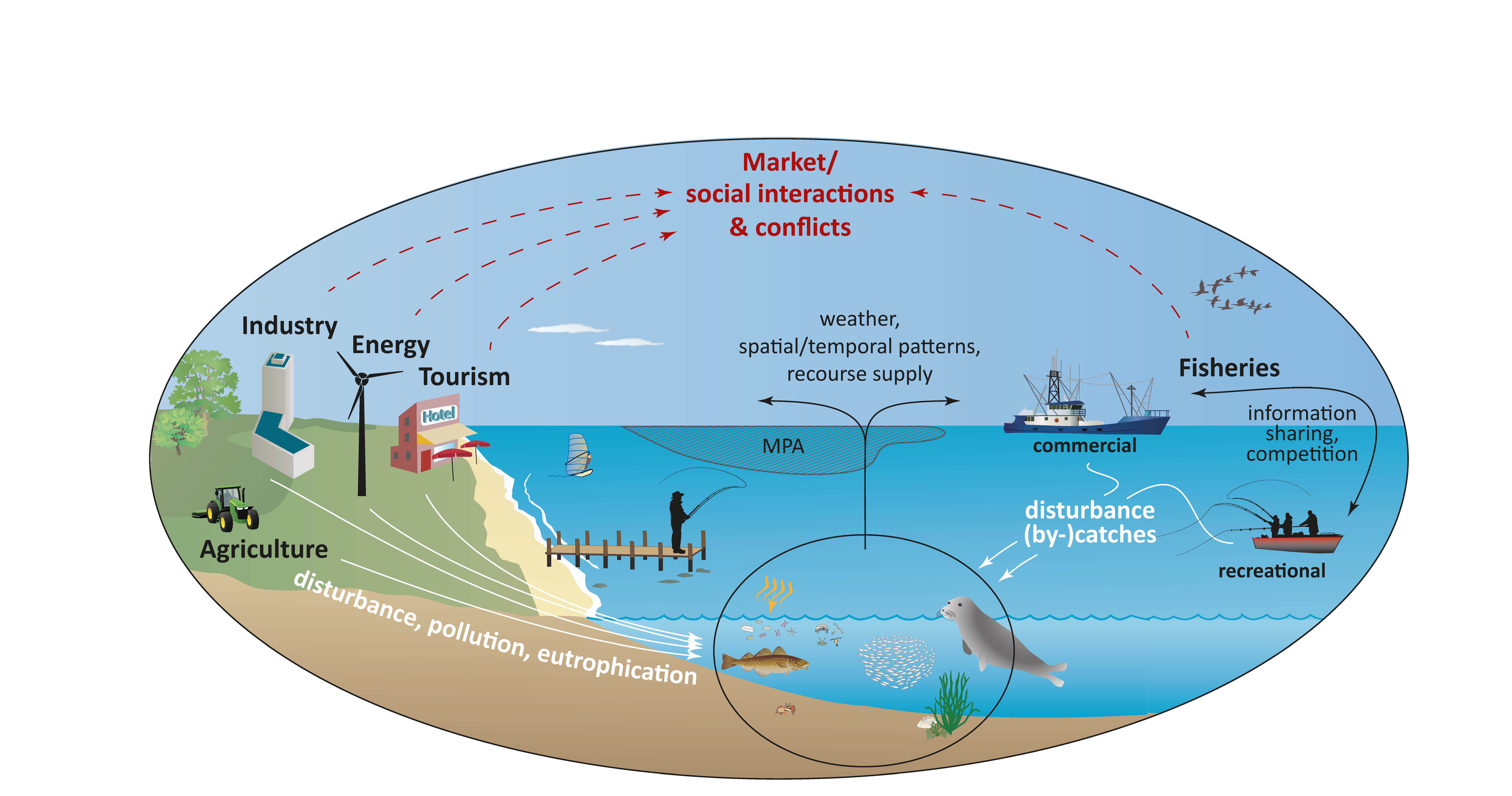
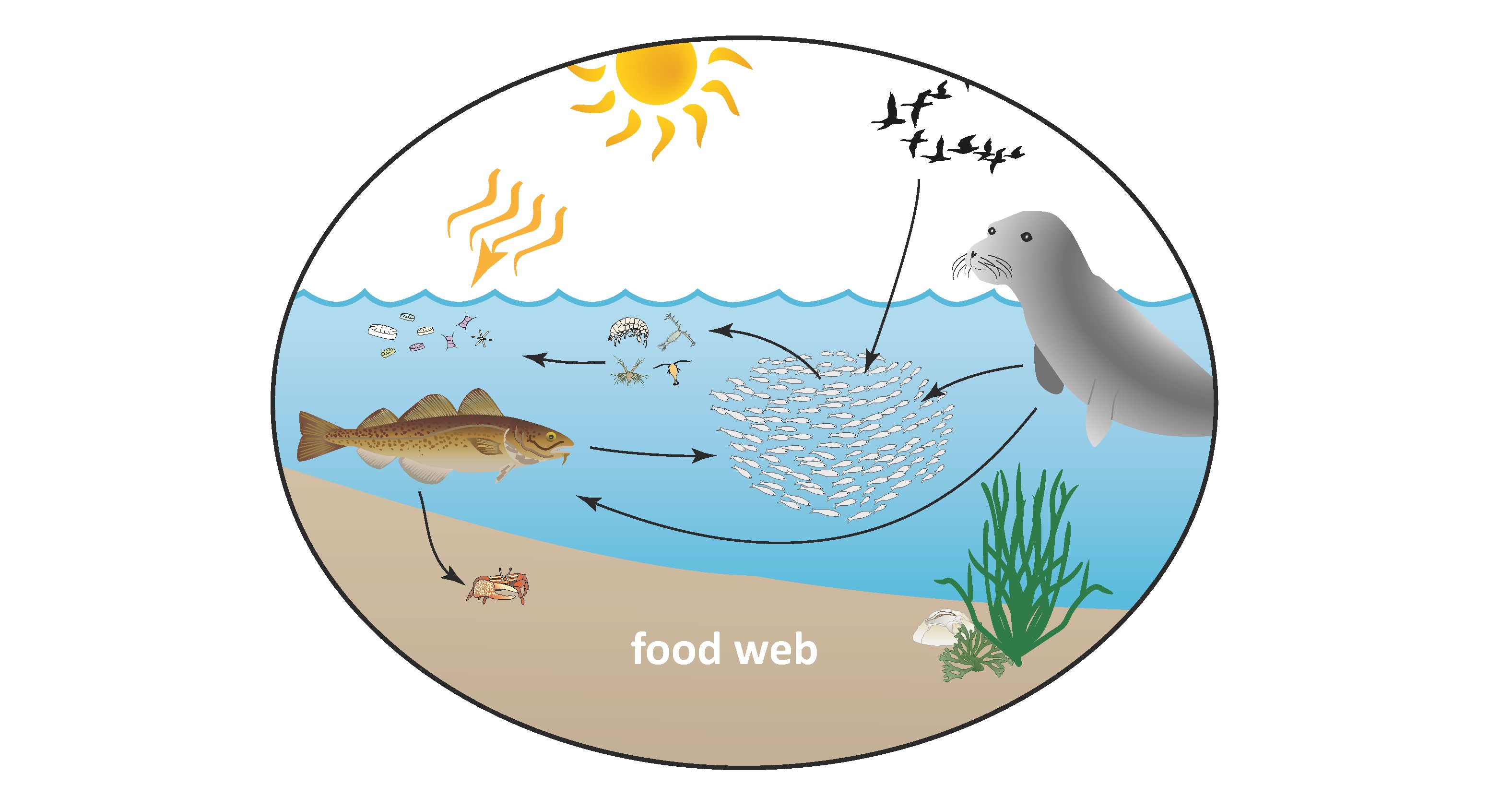
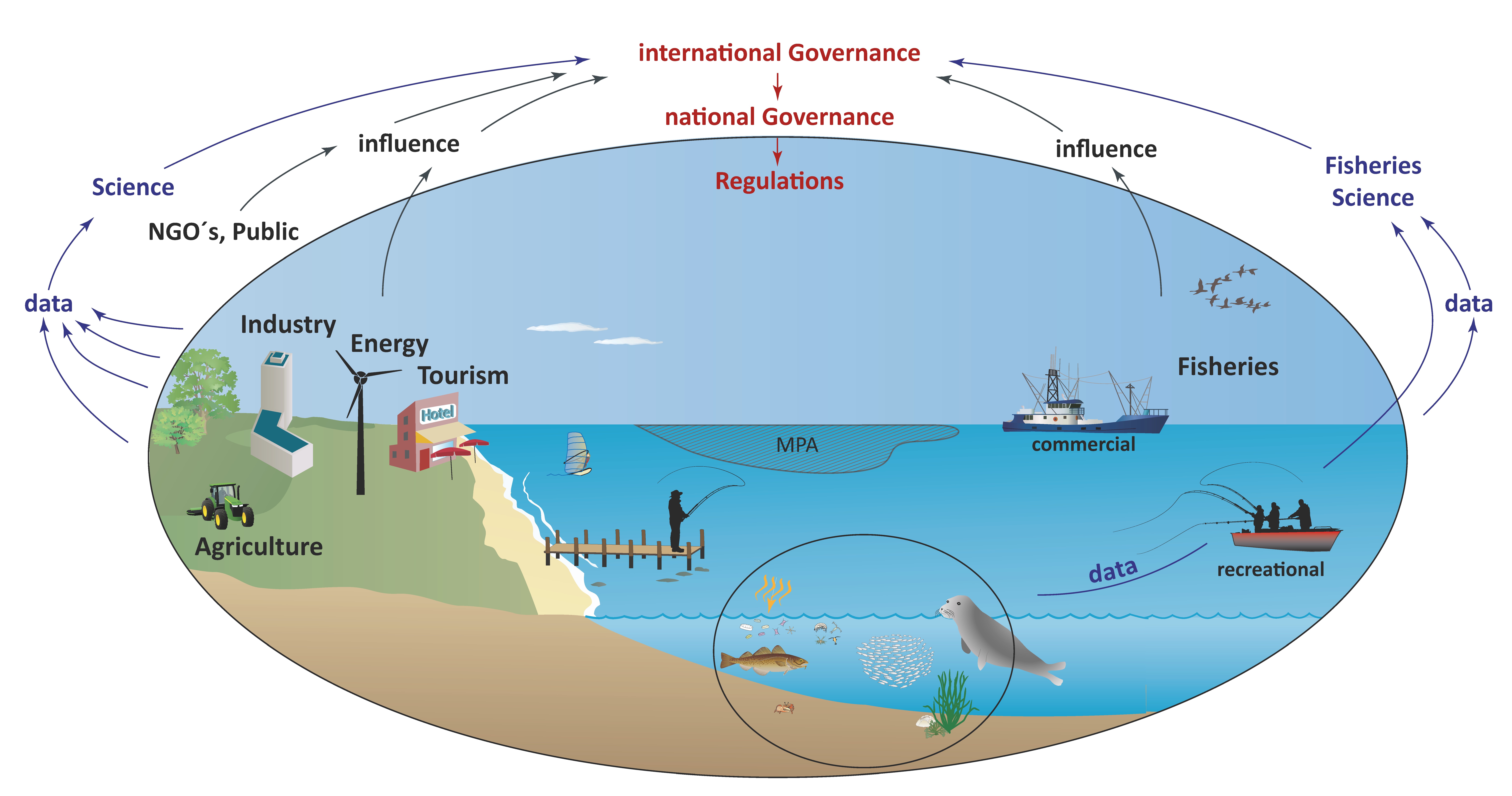
Supplementary materials

# Fisheries social-ecological systems

Commercial and recreational fisheries form social-ecological systems (SESs; Hunt et al. 2013; Weber et al. 2019), consisting of social, ecological, and governmental subsystems (Ostrom 2007). In the social subsystem (Figure 1b) diverse human actors and organizational structures influence each other’s decisions and activities through social norms, cooperation, competition, and knowledge sharing. Whereby these actors influence the resource system with their individual decisions about where, when, what, how often, or how to fish (Allan and Flecker 1993; Lewin et al. 2006). In a fisheries context, the ecological resource system comprises the whole ecosystem with the target fish stock, other species, and the environment (Figure 1a; Hunt et al. 2013). The resource system influences the actors’ decisions due to spatial and temporal variations in the abiotic (weather, wind, etc.) and biotic (stock dynamics, migration, etc.) components (Figure 1b). In addition, the governmental subsystem including the fisheries management applies regulations and constraints on the social subsystem (Figure 1c). The various instruments of fisheries management include input controls such as gear restrictions or output controls such as catch allocations, with the goal of creating sustainable fisheries which simultaneously maintain fish stocks, fishing opportunities, jobs, and user welfare.

(a) Ecological subsystem (b) Ecological and Social subsystem





(c) Total SES

Figure 1: Scheme of a social-ecological fisheries system. (a) shows the ecological subsystem, (b) the social subsystem including the interactions with the ecological subsystem, and (c) the governance subsystem and the interactions with the other subsystems.

# Detailed classification scheme

This table delivers a detailed look at the classification scheme. Each subcategory is described and the predefined values are listed.

Table 1: Review framework with all review categories, evaluations, and descriptions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Category | | | Possible values | Description |
| Overview | General information | Publication title | Free text | What is the title of the reviewed publication? |
| Authors | Free text | Who are the authors of the reviewed publication? |
| Publication year | YYYY | When was the reviewed publication published? |
| Outlet | Free text | In what outlet (e.g. journal) was the reviewed publication published? |
| Topic/research field | Commercial fisheries, recreational fisheries, coastal management | What is the research field or topic of the reviewed publication? |
| Purpose | | explanation/theory-building, guidance of policy/management | Was the purpose of the model a general explanation or the guidance of policies? |
| Main result | | Free text | What is the main result of the publication? |
| Factor of interest | | Policies, behavior, environment | What are the categories of the main factors of interest in the model? (Multiple possible) |
| Free text description | Describe the main factors of interest in the model. |
| Agents | | Representation type | What types of fisher agents are represented in the model? Are they large-scale or small scale? Is the gear active (e.g. bottom or pelagic trawl, purse-seine or calm dredge) or passive (e.g. driftnet, gill net, traps, or longlines)? Regarding the recreational fisheries, are the marine or freshwater and fish the agents from boat, charter boats or shore? |
| Heterogeneity | Are the agents heterogenous within one representation type? For example, have the agents different goals or attributes? |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Social subsystems | Decision-making | Decision mechanism | | Expert opinion, empirical/statistical rules, specific theories | What category describes best the used decision mechanism? When a specific theory is used, name the theory. |
| Free text description | Describe the decision process. |
| Justification of chosen mechanism | | None, general, model-specific | Is there an argumentation why the specific decision mechanism is used? When yes, was the argumentation based on general features of the decision mechanism, or was the argumentation specifically justified with the necessities of this model? |
| Social interactions | Interactions | | None, trading, interference, sharing resources | Are interactions between agents included in the model? When yes, what predefined types fit best? (Multiple possible) |
| Information transfer | | None, indirect (observing), direct (share one item), direct (share multiple items), know everything | Is there an exchange of information between the agents and how does it take place? (Multiple possible) |
| Social network | | None, evolving, static | Is there a social network included in the model? When yes, does the network change during the simulation, or does it stay the same? |
| Social network initialization | | Unknown, random, empirical, manually | How was the social network generated? Manually means that the network is somehow set up by the modeler, without an empirical background. |
| Norms | Social norms | | None, trust, mimicking, social agreement | Are social norms included in the model? When yes, what type of norm is implemented? (Multiple possible) |
| Legal norms/policies | | None, single, multiple | Are legal norms or policies included in the model? When yes, how many are included during the simulation? |
| Legal norms/policies property | | Unknown, static, dynamic | When legal norms/policies are included in the model, are they static or can they change during a simulation run? (Multiple possible) |
| Legal norms/policies types | | Fishing season, closed areas, licenses, gear, quotas, MLS, other | When legal norms/policies are included in the model, what types of legal norms/policies are implemented? (Multiple possible) |
| Adaptation | Learning | | Yes (new decision strategies), yes (information gathering), none | The learning of agents can be represented in two way: 1) The agent learn new decision strategies during the simulation run, 2) the agents gather information in their memory and therefore can improve their performance. |
| Memory | | None, single, multiple | Do the agents have a memory and does it contain single or multiple items? |
| Memory time-frame | | Short-term, long-term | When the agents have a memory, over what time-frame do they save the information? Short-term memory = memories of the last action. Long-term memory = memories over the entire simulation period. |
| Memory property | | Static, accumulating, depleting | When the memory is long-term, does the extend change with the simulation time? (Multiple possible) Static = a amount of the information in the memory does not change within a simulation run. Accumulating = New memories are made and stored with a simulation run. Depleting = the memories disappear with the running time of the simulation. |
| Memory types | | Fishing spots, other locations, catches, economic outcomes, social values | When the agents have a memory, what type of information is remembered? (Multiple possible) |
| Ecological subsystems | Temporal scale | | | Days, weeks, months, years, decades | What is the time-frame of the model (e.g. simulating several years)? When in a publication no simulation run is done, than the time scale is none. |
| Spatial scale | | | None, local, regional, national, international, global | How big is the spatial expansion of the model (e.g. local study of one lake)? |
| Study location | | | Free text | Name the exact location and continent of the study. |
| Ecological complexity | | Biological | single target species, multiple target species, Single target stock, multiple target stocks, bycatch species, other species (NPZD, plankton, prey, predators), species interactions/food web, terrestrial flora/fauna | How complex is the biological subsystem represented? (Multiple possible)  For example, are one ore multiple target stocks and/or other species like aquatic mammals or benthic prey simulated and do the species interact with each other? A stock is defined when the recruitment is explicit implemented, otherwise its called species. |
| Abiotic | Different water bodies (lakes, stream/rivers), habitats, water temperature, hydrodynamics, water chemicals, wind/weather, coastline, seasons, climate change, Regional Ocean Model, terrestrial habitats | How complex is the abiotic subsystem represented? (Multiple possible)  For example, are different water bodies included or are different habitats defined? |
| Social complexity | | Human population | Birth, Dead, aging, population growth, demographic change, living cost, consumption | How complex is human population represented? (Multiple possible) |
| Artificial structures | access points, fishing zones, fishing cost (fuel, crew, maintenance, , travel cost, others), companies, price per catch, market system, catch processing, retailer, fishery management, other jobs opportunities, offshore wind energy, oil platforms, agriculture zones, national parks, urban areas, Hotels, archaeological sites | What artificial structures are implemented in the model? (Multiple possible)  For example, are different harbors or other access points like boat ramps modeled? A distinction is also made as to whether the fish price is fixed or whether a market system with supply/demand is modelled. |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Interaction social and ecological subsystem | Social influences on ecological subsystems | | Decisions influencing the environment | Investment, effort, trip timing, trip length, gear type, site choice, | What decisions are made by the agents which lead to an influence on the biophysical environment? (Multiple possible) |
| Actions influencing the environment | Catch, harvest/release/discard | How do the agents influence the biophysical environment? (Multiple possible) |
| Environment influences on social subsystems | | | wind/weather, fish stock feedback, spatial aspects (distances), spot information, seasonality, hydrodynamics | How does the biophysical environment influence the decision-making of the agents? (Multiple possible) |
| Implementation | Tool/ language | | | R, Python, C++, Netlogo, Comas, Mason Library, Repast simulation toolkit, visual basic | In which modeling tool/language is the ABM implemented? |
| Temporal resolution | | | Discrete-time stepped system, discrete event system, continuous system, a hybrid system | Use the model a discrete-time stepped system (the simulation advances in equidistant time steps), a discrete event system (the simulation advances due to discrete events being scheduled at arbitrary points in continuous time=, a continuous system (the model is a set of differential equations and the simulation relies on numerical integration algorithms), or a hybrid system? When discrete time steps, how big are the steps? |
| Credibility and Reproducibility | Documentation standards | | | None, ODD(+D), TRACE | Are documentation standards used and when yes which one? |
| Provenance | Availability of code | | None, model, model and experiments | Is no code available, when yes only the model code or the code of the model and the experiments? |
| Data driven | | Yes, No | Is the model data driven/ empirical based? |
| Data clarity | | None, some, all | Are all the used data sources clearly described? |
| Data sources | | Interviews, diary, logbook, mandatory fisheries data, local survey, national survey, international survey, expert knowledge, stakeholder knowledge, assumptions, literature, unknown | Where does the data for calibration, validation, and the input parameter come from? (Multiple possible) |
| Data accessibility | | Unknown, private, public | How is the data accessibility? (Multiple possible) |
| Reason for privacy | Is a reason for private data stated? |
| Purpose of the data generation | | Unknown, yes, no | Was the data or part of it especially generated for the model? |
| Data usage | | micro-level data as micro-level input/calibration or as macro-level input/calibration,  macro-level data as micro-level input/calibration or as macro-level input/calibration | For which purpose are the different data levels (micro and macro) used? (Multiple possible) |
| Input parameter clarity | | None, some, all | Are all of the used Input parameters clearly stated? |
| Assumptions & Limitations specified | | None, some, all | Are the underlying assumptions of the model clearly stated? |
| Calibration experiments | | Mentioned, described, available, unknown | Were calibration experiments conducted and how detailed were they described? |
| Validations experiments | | Mentioned, described, available, unknown | Were validation experiments conducted and how detailed were they described? |
| Sensitivity analysis | | Mentioned, described, available, unknown | Were sensitivity analyses conducted and how detailed were they described? |

Table 2: Matrix version of the chord diagram of the overview section (Figure 2).

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | System scale | Com fishery | Rec fishery | Guidance of policy/ management | Explanation/ theory-building | Policies | Behaviour | Environment | Other | None |
| System scale | 10 |  |  | 4 | 6 | 6 | 3 | 1 | 1 | 1 |
| Com fishery |  | 81 |  | 28 | 53 | 30 | 50 | 27 | 1 |  |
| Rec fishery |  |  | 19 | 10 | 9 | 12 | 7 | 3 |  |  |
| Guidance of policy/ management | 4 | 28 | 10 | 42 |  | 35 | 11 | 11 |  |  |
| Explanation/ theory-building | 6 | 53 | 9 |  | 68 | 13 | 49 | 20 | 2 | 1 |
| Policies | 6 | 30 | 12 | 35 | 13 | 48 |  |  |  |  |
| Behaviour | 3 | 50 | 7 | 11 | 49 |  | 60 |  |  |  |
| Environment | 1 | 27 | 3 | 11 | 20 |  |  | 31 |  |  |
| Other | 1 | 1 |  |  | 2 |  |  |  | 2 |  |
| None | 1 |  |  |  | 1 |  |  |  |  | 1 |

Table 3: Matrix version of the chord diagram of the social interaction (Figure 4).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Sharing recourses | Trading | Interference | Cheating | None interaction | Indirect observing | Direct one | Direct multiple | Know everything | Know everything from network | Know parts | Unknown | None information | Static | Evolving | Unknown network | None network |
| Sharing recourses | 1 |  |  |  |  |  |  |  |  |  |  |  | 1 | 1 |  |  |  |
| Trading |  | 9 |  |  |  |  | 1 | 1 | 1 | 1 | 2 |  | 8 | 4 | 2 |  | 5 |
| Interference |  |  | 2 |  |  | 1 |  |  |  |  |  |  | 1 |  | 1 |  | 1 |
| Cheating |  |  |  | 2 |  |  |  |  |  |  |  |  | 2 |  | 2 |  |  |
| None interaction |  |  |  |  | 38 | 14 | 6 | 15 | 3 | 2 | 3 | 1 | 7 | 19 | 1 | 1 | 21 |
| Indirect (observing) |  |  | 1 |  | 14 | 15 |  |  |  |  |  |  |  | 5 | 2 |  | 9 |
| Direct (one) |  | 1 |  |  | 6 |  | 7 |  |  |  |  |  |  | 5 |  | 1 | 4 |
| Direct (multiple) |  | 1 |  |  | 15 |  |  | 15 |  |  |  |  |  | 9 |  |  | 8 |
| Know everything |  | 1 |  |  | 3 |  |  |  | 3 |  |  |  |  | 2 |  |  | 2 |
| Know everything from network |  | 1 |  |  | 2 |  |  |  |  | 3 |  |  |  | 3 |  |  | 2 |
| Know parts |  | 2 |  |  | 3 |  |  |  |  |  | 4 |  |  | 2 |  |  | 2 |
| Unknown |  |  |  |  | 1 |  |  |  |  |  |  | 1 |  |  |  |  | 1 |
| None information | 1 | 8 | 1 | 2 | 7 |  |  |  |  |  |  |  | 16 | 10 | 2 |  | 9 |
| Static | 1 | 4 |  |  | 19 | 5 | 5 | 9 | 2 | 3 | 2 |  | 10 | 23 |  |  |  |
| Evolving |  | 2 | 1 | 2 | 1 | 2 |  |  |  |  |  |  | 2 |  | 4 |  |  |
| Unknown network |  |  |  |  | 1 |  | 1 |  |  |  |  |  |  |  |  | 1 |  |
| None network |  | 5 | 1 |  | 21 | 9 | 4 | 8 | 2 | 2 | 2 | 1 | 9 |  |  |  | 25 |

Table 4: Matrix version of the chord diagram of the legal norms/policies (Figure 5).

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | One | Multiple | Static | Dynamic | Input areas | Input fishing season | Input effort | Input gear | Output quotas | Output MLS | Output bag limit | Other |
| One | 42 |  | 28 | 14 | 19 | 3 | 1 | 1 | 11 | 3 |  | 2 |
| Multiple |  | 24 | 24 | 10 | 13 | 6 | 3 | 4 | 18 | 6 | 3 | 5 |
| Static | 28 | 48 | 76 |  | 28 | 6 | 5 | 4 | 13 | 10 | 3 | 7 |
| Dynamic | 14 | 10 |  | 24 | 4 | 3 |  | 1 | 16 |  |  |  |
| Input areas | 19 | 13 | 28 | 4 | 32 |  |  |  |  |  |  |  |
| Input fishing season | 3 | 6 | 6 | 3 |  | 9 |  |  |  |  |  |  |
| Input effort | 2 | 3 | 5 |  |  |  | 5 |  |  |  |  |  |
| Input gear | 1 | 4 | 4 | 1 |  |  |  | 5 |  |  |  |  |
| Output quotas | 11 | 18 | 13 | 16 |  |  |  |  | 29 |  |  |  |
| Output MLS | 4 | 6 | 10 |  |  |  |  |  |  | 10 |  |  |
| Output bag limit |  | 3 | 3 |  |  |  |  |  |  |  | 3 |  |
| Other | 2 | 5 | 7 |  |  |  |  |  |  |  |  | 7 |

Table 5: Matrix version of the chord diagram of the memory (Figure 6).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Single | Multiple | Short term | Long term | Static | Dynamic accumulating | | Dynamic both | Fishing spots | | Other locations | Social value | Catches | | Economic outcomes | Rules | | Effort | Stock status |
| Single | 38 |  | 14 | 26 | 9 | 8 | 9 | | 9 |  | | 2 | 16 | 8 | | |  | 1 | 2 |
| Multiple |  | 34 | 4 | 33 | 2 | 22 | 9 | | 27 | 3 | |  | 24 | 6 | | | 2 | 4 | 1 |
| Short term | 14 | 4 | 17 |  |  |  |  | | 7 |  | |  | 7 | 5 | | |  | 2 |  |
| Long term | 26 | 33 |  | 58 | 11 | 30 | 17 | | 31 | 3 | | 2 | 35 | 10 | | | 2 | 4 | 3 |
| Static | 9 | 2 |  | 11 | 11 |  |  | | 5 |  | | 2 | 3 | 3 | | |  |  |  |
| Dynamic accumulating | 8 | 22 |  | 30 |  | 30 |  | | 18 | 3 | |  | 20 | 4 | | | 2 | 2 | 2 |
| Dynamic both | 9 | 9 |  | 17 |  |  | 17 | | 8 |  | |  | 12 | 3 | | |  | 2 | 1 |
| Fishing spots | 9 | 27 | 7 | 31 | 5 | 18 | 8 | | 35 |  | |  |  |  | | |  |  |  |
| Other locations |  | 3 |  | 3 |  | 3 |  | |  | 3 | |  |  |  | | |  |  |  |
| Social value | 2 |  |  | 2 | 2 |  |  | |  |  | | 2 |  |  | | |  |  |  |
| Catches | 16 | 24 | 7 | 35 | 3 | 20 | 12 | |  |  | |  | 40 |  | | |  |  |  |
| Economic outcomes | 8 | 6 | 5 | 10 | 3 | 4 | 3 | |  |  | |  |  | 14 | | |  |  |  |
| Rules |  | 2 |  | 2 |  | 2 |  | |  |  | |  |  |  | | | 2 |  |  |
| Effort | 1 | 4 | 2 | 4 |  | 2 | 2 | |  |  | |  |  |  | | |  | 5 |  |
| Stock status | 2 | 1 |  | 3 |  | 2 | 1 | |  |  | |  |  |  | | |  |  | 3 |

Table 6: Matrix version of the chord diagram of the interactions of the social and ecological subsystem (Figure 7).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Fishery entry/ exit | Investment | Sell/ buy Quota | Effort | Trip timing | Gear typ | Site choice | Port choice | Trip length | harvest/release | Chose fishbuyer | None | Spatial aspects | Spot information | Fishstock feedback | Wind/weather | Hydrodynamics | Seasonality | Water characteristics | None environment |
| Fishery entry/ exit | 7 |  |  |  |  |  |  |  |  |  |  |  | 2 | 3 | 5 |  |  |  |  | 1 |
| Investment |  | 2 |  |  |  |  |  |  |  |  |  |  | 1 | 1 | 1 |  |  |  |  |  |
| Sell/ buy Quota |  |  | 4 |  |  |  |  |  |  |  |  |  | 3 | 2 | 3 |  |  |  |  |  |
| Effort |  |  |  | 46 |  |  |  |  |  |  |  |  | 11 | 18 | 25 | 4 |  | 1 | 3 | 4 |
| Trip timing |  |  |  |  | 10 |  |  |  |  |  |  |  |  | 9 | 1 |  |  |  |  |  |
| Gear typ |  |  |  |  |  | 5 |  |  |  |  |  |  | 2 | 1 | 4 |  |  |  |  |  |
| Site choice |  |  |  |  |  |  | 85 |  |  |  |  |  | 39 | 44 | 53 | 12 | 2 | 2 | 3 | 2 |
| Port choice |  |  |  |  |  |  |  | 5 |  |  |  |  | 5 | 2 | 4 | 1 |  |  |  |  |
| Trip length |  |  |  |  |  |  |  |  | 21 |  |  |  | 11 | 15 | 11 | 6 |  |  |  |  |
| harvest/release |  |  |  |  |  |  |  |  |  | 4 |  |  | 2 | 2 | 2 |  |  |  |  |  |
| Chose fishbuyer |  |  |  |  |  |  |  |  |  |  | 7 |  | 2 |  |  |  |  |  |  | 5 |
| None |  |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |  |  |  | 2 |
| Spatial aspects | 2 | 1 | 3 | 11 |  | 2 | 39 | 5 | 11 | 2 | 2 |  | 41 |  |  |  |  |  |  |  |
| Spot information | 3 | 1 | 2 | 18 | 9 | 1 | 44 | 2 | 15 | 2 |  |  |  | 44 |  |  |  |  |  |  |
| Fishstock feedback | 5 | 1 | 3 | 25 | 1 | 4 | 53 | 4 | 11 | 2 |  |  |  |  | 68 |  |  |  |  |  |
| Wind/weather |  |  |  | 4 |  |  | 12 | 1 | 6 |  |  |  |  |  |  | 12 |  |  |  |  |
| Hydrodynamics |  |  |  |  |  |  | 2 |  |  |  |  |  |  |  |  |  | 2 |  |  |  |
| Seasonality |  |  |  | 1 |  |  | 2 |  |  |  |  |  |  |  |  |  |  | 3 |  |  |
| Water characteristics |  |  |  | 3 |  |  | 3 |  |  |  |  |  |  |  |  |  |  |  | 3 |  |
| None environment | 1 |  |  | 4 |  |  | 2 |  |  |  | 5 | 2 |  |  |  |  |  |  |  | 10 |

# Fisheries ABM classification scheme

The following tables list the results of the classification scheme of all reviewed publications.

Table 3: Overview (part 1)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **ID** | **Publication title** | **Author** | **Publication year** | **Outlet** | **Topic/research field** | **Purpose** |
| 1 | “An agent-based model to optimize transboundary management for the walleye pollock (*Gadus chalcogrammus*) fishery in the Gulf of Alaska” | Williams, Criddle, and Kruse | 2021 | Natural Resource Modeling | Com. fishery | Guidance of policy/ management |
| 2 | “The interplay between top-down interventions and bottom-up self-organization shapes opportunities for transforming self-governance in small-scale fisheries” | Schlüter, Lindkvist, and Basurto | 2021 | Marine Policy | Com. fishery | Explanation/theory building |
| 3 | “Modeling the impacts of floating seaweeds on fisheries sustainability in Ghana” | Ofori and Rouleau | 2021 | Marine Policy | Com. fishery | Guidance of policy/ management |
| 4 | “Projected Shifts in 21st Century Sardine Distribution and Catch in the California Current” | Fiechter et al. | 2021 | Frontiers in Marine Science | Com. fishery | Explanation/theory building |
| 5 | “Behavioural diversity in fishing—Towards a next generation of fishery models” | Wijermans et al. | 2020 | FISH and FISHERIES | Com. fishery | Explanation/theory building |
| 6 | “Simulating the effects of environmental and market variability on fishing industry structure” | Thanassekos and Scheld | 2020 | Ecological Economics | Com. fishery | Explanation/theory building |
| 7 | “How fisher behavior can bias stock assessment: insights from an agent-based modelling approach” | Saul, Brooks, and Die | 2020 | Canadian Journal of Fisheries and Aquatic Sciences | Com. fishery | Explanation/theory building |
| 8 | “Effects of cooperation and different characteristics of Marine Protected Areas in a simulated small-scale fishery” | Owusu et al. | 2020 | Ecological Complexity | Com. fishery | Explanation/theory building |
| 9 | “AGENT-BASED MULTICOMPONENT SPATIAL SIMULATION OF A FISHERY” | Idda et al. | 2020 | SummerSim ’20: Proceedings of the 2020 Summer Simulation Conference | Com. fishery | Explanation/theory building |
| 10 | “From reactive towards anticipatory fishing agents” | Madsen et al. | 2020 | Journal of Simulation | Com. fishery | Explanation/theory building |
| 11 | “SIMSEA: A Multiagent Architecture for Fishing Activity in a Simulated Environment” | Cascalho et al. | 2019 | Proceedings of the 11th International Conference on Agents and Artificial Intelligence | Com. fishery | Guidance of policy/ management |
| 12 | “A computational approach to managing coupled human-environmental systems” | Bailey et al. | 2019 | Sustainability Science | Com. fishery | Guidance of policy/ management |
| 13 | “Balanced harvesting can emerge from fishing decisions by individual fishers in a small-scale fishery” | Plank et al. | 2017 | FISH and FISHERIES | Com. fishery | Guidance of policy/ management |
| 14 | “Micro-level explanations for emergent patterns of self-governance arrangements in small-scale fisheries—A modeling approach” | Lindkvist, Basurto, and Schlüter | 2017 | PLoS ONE | Com. fishery | Explanation/theory building |
| 15 | “Exploring benefits of spatial cooperative harvesting in a sea urchin fishery” | Gutierrez et al. | 2017 | Ecosphere | Com. fishery | Explanation/theory building |
| 16 | “How will the Kenai fisheries respond to changing environmental conditions: scenario based studies of coupled socioecological systems dynamics using an agent-based model” | Cenek et al. | 2017 | OCEANS17 MTS/IEEE Conference: Our Harsh and Fragile Ocean | Com. fishery | Guidance of policy/ management |
| 17 | “An adaptable agent-based model for guiding multi-species Pacific salmon fisheries management within a SES framework” | Cenek and Franklin | 2017 | Ecological Modelling | Com. fishery | Guidance of policy/ management |
| 18 | “Developing High Fidelity, Data Driven, Verified Agent Based Models of Coupled Socio-Ecological Systems of Alaska Fisheries” | Cenek and Franklin | 2016 | Proceedings of GIScience 2016 Workshop on Rethinking the ABCs: Agent-Based Models and Complexity Science in the age of Big Data, CyberGIS, and Sensor Networks | Com. fishery | Guidance of policy/ management |
| 19 | “Demonstration of a fully-coupled end-to-end model for small pelagic fish using sardine and anchovy in the California Current” | Rose et al. | 2015 | Progress in Oceanography | Com. fishery | Explanation/theory building |
| 20 | “Effects of social factors on fishing effort” | Libre et al. | 2015 | Fisheries Research | Com. fishery | Explanation/theory building |
| 21 | “The role of environmental controls in determining sardine and anchovy population cycles in the California Current” | Fiechter et al. | 2015 | Progress in Oceanography | Com. fishery | Explanation/theory building |
| 22 | “DISPLACE: a dynamic, individual-based model for spatial fishing planning and effort displacement — integrating underlying fish population models” | Bastardie, Nielsen, and  Miethe | 2014 | Canadian Journal of Fisheries and Aquatic Sciences | Com. fishery | Explanation/theory building |
| 23 | “A companion modeling approach applied to fishery management” | Worrapimphong et al. | 2010 | Environmental Modelling & Software | Com. fishery | Guidance of policy/ management |
| 24 | “Effects of fishing effort allocation scenarios on energy efficiency and profitability” | Bastardie, Nielsen, Andersen, et al. | 2010 | Fisheries Research | Com. fishery | Explanation/theory building |
| 25 | “An agent-based model for simulating trading of multi-species fisheries quota” | Little et al. | 2009 | Ecological Modelling | Com. fishery | Guidance of policy/ management |
| 26 | “The precursors of governance in the Maine lobster fishery” | Wilson, Yan, and Wilson | 2007 | Proceedings of the National Academy of Sciences | Com. fishery | Explanation/theory building |
| 27 | “Modeling fleet response in regulated fisheries” | Soulie and Thebaud | 2006 | Mathematical and Computer Modelling | Com. fishery | Guidance of policy/ management |
| 28 | “Coupling Biophysical and Socioeconomic Models for Coral Reef Systems in Quintana Roo, Mexican Caribbean” | Melbourne-Thomas et al. | 2011 | Ecology and Society | Coastal management | Explanation/theory building |
| 29 | “An Agent-Based Model to Address Coastal Management Issues in the Yucatan Peninsula, Mexico” | Perez et al. | 2009 | 18th World IMACS/MODSIM Congress | Coastal management | Explanation/theory building |
| 30 | “Exploring social ecological trade-offs in fisheries using a coupled food web and human behavior model” | Innes-Gold et al. | 2021 | Ecology and Society | Rec. fishery | Explanation/theory building |
| 31 | “A modelling approach to evaluate the impact of fish spatial behavioural types on fisheries stock assessment” | Alos, Campos-Candela, and Arlinghaus | 2019 | ICES Journal of Marine Science | Rec. fishery | Explanation/theory building |
| 32 | “Site closure management strategies and the responsiveness of conservation outcomes in  recreational fishing” | Gao and Hailu | 2018 | Journal of Environmental Management | Rec. fishery | Guidance of policy/ management |
| 33 | “Use of surveys and agent-based modelling to assess the management implications of the behaviours of specialised recreational boat fishers” | Tink | 2015 | Dissertation at the Murdoch University, Western  Australia | Rec. fishery | Explanation/theory building |
| 34 | “Ranking management strategies with complex outcomes: An AHPfuzzy evaluation of recreational fishing using an integrated agent-based model of a coral reef ecosystem” | Gao | 2012 | Environmental Modelling | Rec. fishery | Guidance of policy/ management |
| 35 | “Evaluating the effects of area closure for recreational fishing in a coral reef ecosystem” | Gao and Hailu | 2011 | Ecological Economics management | Rec. fishery | Guidance of policy/ management |

Table 4: Overview (part 2)

|  |  |  |  |
| --- | --- | --- | --- |
| **ID** | **Main result** | **Factor of interest** | **Factor of interest description** |
| 1 | A scenario that allows community-base-cooperatives in federal waters and an open access strategy in state waters produced the best overall improvements under conditions characteristic of the recent past relative to the status quo. | Policies | Eleven different management scenarios |
| 2 | Under environmental and social uncertainties, a combination of financial and social support over longer periods of time is needed to ensure the persistence of new forms of governance in the face of competition with established forms. | Policies, Behavior, Environment | Policies = Financial support as increased coop capital, increased loyalty as social support.  Behavior = frequent (once a month) and infrequent (once a year) conflicts reflected as sudden loyalty loss.  Environment= Environmental variability (bad weather) modeled as stochastic catchability reflecting difficulties of going out fishing or securing catches. |
| 3 | Fishery managers can take advantage of floating seaweeds to naturally regulate fishing mortality and maximize fish stocks and landings in the long-term, by leaving behind 25% of relative seaweed biomass in each fishing zone every week. | Policies | Five different seaweed removal scenarios. |
| 4 | Regional end to end (“physics to fish”) models for population responses of higher trophic organisms to climate change can benefit from the downscaling of multiple earth-system models. | Environment | Climate change scenarios |
| 5 | The comparison of FIBE and a theoretical measure of optimal management showed that none of the empirically based modelling of fishing behaviour is close to traditional optimal management. In addition, FIBE was able to show the effects of a fuel subsidy, demonstrating how policy influences behaviour. | Policies,  Behavior | Fishers’ behavioral diversity and a policy intervention (fuel subsidy). |
| 6 | Changes in fishery variability affect the composition of risk preferences within the fleet, leading to changes in the economic and biological importance of fisheries. Market stability does not dampen the negative impacts of environmental variability, but rather encouraged overinvestment and increased removals by a small number of risk-taking fishers. A climate-induced increase in fisheries variability and increased market integration, could weaken local price signals and lead to inefficient investments and reduced fish resources. | Environment | Environmental variability is represented by fishing success variability and market variability is represented by the price elasticity of demand. |
| 7 | Management advice from assessment models based on fishery-dependent data could be biased and lead to overestimation of fishing mortality and biased estimates of population status. | Other | Stock assessment model configurations (4 different ways) are compared with the ABM simulation. |
| 8 | A high level of cooperation without an MPA can be as effective as a lower level of cooperation in combination with an MPA in maintaining fish stocks and catches at relatively high levels. Furthermore, the greatest impact on fish stocks and catches will come from the size of an MPA and the time elapsed since its establishment. | Policies,  Behavior | Fishing strategies (cooperation levels) and various MPA settings. |
| 9 | ABM-MC (Agent-Based Multicomponent Modelcompositional) modelling facilitates computer modelling and simulation of fisheries. | Policies | Protection/closure of one of three fishing zones |
| 10 | That agents mimic real-world behaviors is evidence that reason-based cognitive decisions enable anticipatory behavioral adaptation. | Policies,  Behavior | New decision theory compared to Bailey et al. 2019 and different policies (e.g. MPA) |
| 11 | Agents profiles and the variability in the biomass index may influence the fishing profit. | Behavior | Fishing price and different agent profile (optimistic, pessimistic, medium vessels and for a mixed group consisting of half optimistic and half pessimistic vessels) to simulate different levels of risk aversion/ risk seeking. |
| 12 | POSEIDON is able to replicate known behavioral characteristics of fishing fleets in response to a wide range of management measures, suggesting considerable potential for real-world applications once additional empirically-based complexity is incorporated. The explore-exploit-imitate (EEI) algorithm provides a simple approach to developing adaptive fleet response. It is also possible to generate hybrid policies using an optimizer.  ) | Policies | Broad set of policies including MPAs, gear restrictions, TAC and ITAC. |
| 13 | Balanced harvesting can emerge without external intervention under some circumstances. | Behavior | The size selectivity of individual fishermen. |
| 14 | PCs cope better when there are large differences in reliability between fishermen and low initial trust between them, as this makes it more difficult to establish cooperatives. Cooperatives cope better with seasonal fluctuations in fish abundance and offer long-term security to fishermen once they are established. | Behavior | Two ways how the fishers organize: hierarchical noncooperative arrangements between fishers and fish buyers, such as patron-client relationships (PCs), and more cooperative arrangements among fishers, such as fishing cooperatives (coops). |
| 15 | Well-functioning cooperatives (good information sharing and organised harvesting) enabled fishermen to optimise the use of the resource by achieving higher gonad yields per unit of effort while maintaining the productivity of the stock. | Behavior | Four fishing scenarios with different harvest behavior from non-cooperative to cooperative harvest, different knowledge levels (last month, historical, perfect) and selectivity strategies  (take all to take only when good yield) |
| 16 | The management of the commercial fishery has a much higher adaptive capacity to changing ecological factors than the management strategy for the set gillnet fishery. A change in net depth could reduce the bycatch of Chinook. | Environment | The run timing of Sockeye and Chinook change stochastically. |
| 17 | In the past, the CSES (socio-ecological dynamics) dynamics on the Kenai River of the drift gillnet fishery were unstable because the fishing strategy was compensatory and aggressive. Currently, the dynamics of the set gillnet fishery are unstable. | Environment | The run timing of Sockeye and Chinook change stochastically. |
| 18 | ABM construction and validation, which can be used for other fisheries and as decision support tool for fishery managers. | Environment | The run timing of Sockeye and Chinook change stochastically. |
| 19 | It is possible to perform multi-decadal simulations of a fully coupled end-to-end model, where the model models individual fish and boats on the same three-dimensional grid as the hydrodynamics. | Environment | Detailed model of hydrology and the ecosystem. |
| 20 | Viewing fisheries as a complex adaptive system in which social factors and bounded rationality have a significant influence on fishermen's decisions can improve both fisheries research and fisheries management. | Behavior | three social factors and bounded rationality |
| 21 | End-to-end ecosystem model provides valuable insight on potential relationships between environmental conditions and sardine and anchovy population dynamics | Environment | Detailed variation in biological and environmental parameter. |
| 22 | Integrating the spatial activity of vessels and fish abundance dynamics allow a more realistic predictions of fisher behavior, profits, and stock abundance. | Behavior | Scenarios for trip planning and fishing effort displacement. |
| 23 | Management through rotating reserves is not efficient if the duration of reserves is too short. | Policies | Alternative scenarios with closed zones or quota systems |
| 24 | Potential gain in efficiency due to effort allocation is balanced out with possible losses in total landings and revenue. | Behavior | Alternative scenarios of fuel saving behavior. |
| 25 | An ITQ system can lead to a reduction in fishing effort, an increase in profits and a change in quota prices for the CRFFF over time. As an ecological consequence of the ITQ system, there are increased catches and discards of the less profitable species, even though a TAC has been set. | Policies | Three levels of TACs. |
| 26 | Fishers in a scramble to find the lobsters first do not generate the boundaries necessary for effective collective action. Fishers to compete with one another by direct and costly interference lay the foundation for successful collective actions. | Behavior | Kinds of competition: scramble competition, in which fishers race to find the patchy resource, and interference competition, in which fishers destroy traps used by other fishers. |
| 27 | The great complexity in fishing effort and fish biomass with cascading effects between different zones leads to complicated adaptations of a measure such as a partial fishing ban. | Policies | Closed fishing zones. |
| 28 | The coupled model system (biophysical and socio-economic ABM) provides reasonable predictions for fisheries and ecological variables in the scenarios studied, which can be used to examine future socio-ecological change in Quintana Roo. | Other | Population and tourism growth. |
| 29 | SimReef can integrate social, economic and ecological compartments into a coherent framework. | None |  |
| 30 | High commercial removals of forage fish resulted in lower piscivorous fish biomass, but had minimal impact on the number of recreationally caught fish or recreational fishers' satisfaction. Fish biomass, number of recreationally caught fish and recreational fishers' satisfaction are sensitive to the chosen abundance-catch relationship and loss of satisfaction.  ABMs are able to model the behavior of fishers in a social-ecological system. The integration of recreational fishers has an impact on the ecosystem. | Policies,  Behavior,  Environment | Three different types of catch-abundance relationship, four levels of commercial harvest, and different types of satisfaction loss. |
| 31 | Hyperdepletion (CPUE decline faster than N) can occure when SBTs (spatial behavioral types of fish) exist. Therefore, consideration of SBT can improve stock assessments by providing a more realistic CPUE-N relationship. | Environment | Two scenarios: with and without the existence of spatial behavioral types of fish. |
| 32 | More stringent site closure strategies do not necessarily provide increased benefits. | Policies | Different site closures (total of 12 combinations of length (0,2, and 6 month), number of sites closed (1,5, and 9) and timing (peak and off-peak). |
| 33 | More avid and specialized of anglers can maintain their catches by adapting and altering their behaviors in response to changes. | Policies,  Behavior | Different management options and ways to search and update the own knowledge of good spots. |
| 34 | To support the decision-making of managers in a complex decision-making situation with multiple management objectives and strategies, the ABM + AHPfuzzy system can be used. | Policies | Site closure of 2 and 6 month and high/low fishing pressure scenarios. |
| 35 | Without integrated modelling, one would have expected not only different effects, but also different spatial and temporal impacts of management measures, | Policies | Site closure of 2 and 6 month and high/low fishing pressure scenarios. |

Table 5: Social subsystems - Decision making. Text in "" corresponds to a verbatim quote from the respective publication.

|  |  |  |  |
| --- | --- | --- | --- |
| **ID** | **Decision mechanism** | **Justification of chosen mechanism** | **Decision mechanism description** |
| 1 | Bounded rational choice | None | Stochastic rules in participation, catch, trip duration. Set of simple behavioral rules that drive the choice of fishing location and port of delivery which maximizes their expected net revenue. |
| 2 | Empirical/statistical rules | Model-specific | Buyers decide on what fisher to work with and takes the fisher with maximum reputation. Fisher decides to cheat based on loyalty and reliability. |
| 3 | Empirical/statistical rules | Model-specific | First choose random location, if it gives 25% of expected catch choose the same again, if not choose another random location next time. |
| 4 | Random utility | General considerations | Agents maximize the expected net revenue with multinomial logit (a form of random utility models). |
| 5 | Bounded rational choice | Model-specific | Maximization of profit and/or home time or satisfaction of needs depending on agent typ. |
| 6 | Empirical/statistical rules | None | Statistical functions of decisions: one daily decision (fishing), three annual decisions (fishing entry, fishing exit, investment). “The decision to go fishing happens when: the product of the difference between an individual's average income yesterday and the variance of average income is higher than the individual's costs/preferences towards fishing. Entering the fishery and investing happens when: the daily expectation of individual net benefits associated with the fishery is higher than the investment costs. Exiting the fishery happens when: the daily expectation of individual net benefits from the fishery is lower than the scrap value of fishery capital investments.” |
| 7 | Empirical/statistical rules | None | The decision to go out and return was statistically modelled. “The decision to go fishing on a given day was determined by the seasonal legal closures for certain species groups, fuel price, wind speed and frequency of trips in the commercial fishery. The decision whether to go back to port depends on the following factors: seasonal closures, fuel price, fish price, day of the week (no landing allowed on weekends) and the ratio between the current catch volume and the total capacity of the fish loader. Site selection was modelled using a multinomial mixed logistic model that takes into account distance to port, expected revenue, wind speed, custom and fuel cost.” |
| 8 | Expert opinion | None | Chose a random direction and move 0.3 length or choose direction of other agent with highest catch and move 0.3 length in this direction. |
| 9 | Expert opinion | None | Explained conceptual: Economic behavior through local operating rules like maximization of income. |
| 10 | Erotetic theory of decision | General considerations and model-specific | “Agents pose the question “where should I fish?” corresponding to the set of alternative map locations for each step. Agent consults a set of priorities that it sequentially treats as partial answers. These priorities are one of the main parameters for specifying a particular kind of agent.” |
| 11 | Bounded rational choice | Model-specific | “Multi-criteria decision-making mechanism with the concept of risk aversion/risk seeking (different agent profiles). Two criteria for selecting a fishing ground are applied: the distance from the port of origin and the fish biomass index. A profile is defined by weighting the two criteria differently.” |
| 12 | Bandit problems | None | Choose randomly first, compare result with network, depending on the comparison us same as before, copy other or make a new random choice. Choice to copy, repeat or exploit is based on profit maximization. |
| 13 | Expert opinion | None | Fisher’s choice of target size is completely random, but if the fisher happen to choose a target size that gives a relatively large catch, the fisher is more likely to continue with that target size. |
| 14 | Empirical/statistical rules | Model-specific | “Buyers decide on what fisher to work with by taking the fisher with the maximum reputation. If the reliability of a fisher is larger than a random number and loyalty index is less than another random number and third, there is another organization to sell catch to, the fisher will cheat.” |
| 15 | Rational choice | None | Decision mechanism differ from random to perfect knowledge/maximization (rational choice). Location choice can be random, depend on historical knowledge or pick the best in terms of total gonad yield with perfect knowledge. Selectivity can be none or take only sea urchins with a high quality. |
| 16 | Bounded rational choice | None | New fishing location is chosen, when current harvest is lower than expected harvest, harvest of the day before or harvest of surrounding agents. |
| 17 | Bounded rational choice | None | New fishing location is chosen, when current harvest is lower than expected harvest, harvest of the day before or harvest of surrounding agents. |
| 18 | Bounded rational choice | Model-specific | New fishing location is chosen, when current harvest is lower than expected harvest, harvest of the day before or harvest of surrounding agents. |
| 19 | Random utility | General considerations | Agents maximize the expected net revenue with multinomial logit (a form of random utility models). |
| 20 | Bounded rational choice | None | Agents decision rules are based on probability functions. E.g. ”probability that a company will sell a vessel increases when (1) the ratio of actual catch to target catch of the company’s vessels for the year decreases, and (2) the proportion of company vessels with positive profit at the end of the year decreases.” |
| 21 | Random utility | General considerations | Agents maximize the expected net revenue with multinomial logit (a form of random utility models). |
| 22 | Empirical/statistical rules | None | Logical behavior rules from Bastardie et al. 2010, for example: “If the fisher want to change the fishing ground, then choose a random fishing ground.” |
| 23 | Empirical/statistical rules | None | Fixed probability to go fishing (2/3), random number of cells (between 100-200) visit per day, random proportion (0.3-1) of clams harvested per cell. Decision to move to neighbor cell with highest calms density. |
| 24 | Empirical/statistical rules | None | Logical behavior rules from Bastardie et al. 2010, for example: “If the fisher want to change the fishing ground, then choose a random fishing ground.” |
| 25 | Rational choice | Model-specific | Fishers allocate their effort to maximize their profit.”The key elements for selecting a new fishing location are: (1) travel time (or its surrogate travel distance); (2) bearing to the next reef relative to the general direction of travel; (3) size of the potential destination reef; and (4) catch expected at each potential destination reef based on prior experience by the vessel and the commercial fishing fleet.” |
| 26 | Bounded rational choice | None | Fishers try to maximize their profit: Therefore, they observe the environment, check their memory for rules and similar circumstances. When they find a fitting rule, they use the best weighted rule, if it performs good again the weight is increased, if it performs bad the weight is decreased. If no rules exist for this circumstance, agents create a new rule. |
| 27 | Rational choice | None | Agents have perfect information’s of CPUE per zone and chose the zone and species that give the highest profit margin. |
| 28 | Unknown | None | Fishing fleets assess the seasonal profitability of their fishing grounds and can select alternative fishing areas based on previous catches. |
| 29 | Unknown | None | Fishing fleets are able to assess the seasonal profitability of their fishing grounds and to eventually select another area based on recorded catches. |
| 30 | Empirical/statistical rules | None | If successful, the fisher becomes more likely to fish again at the subsequent time step. Additionally, some stochastic probabilities: fish natural mortality, release mortality, a fisher’s decision to fish, likelihood of catch, and likelihood of keeping a fish. |
| 31 | Expert opinion | None | Random start points for fishing, then two walk movement model (searching with tendency towards other fisher boats and fishing) and a probability matrix to switch states. |
| 32 | Random utility | General considerations | “The probability that an agent chooses a site from all sites is depending on the expected utilities from each of those sites. The utility depends on including cost, expected catch rate, site attributes and angler characteristics.” |
| 33 | Empirical/statistical rules | None | Set of (stochastic) probabilistic rules. For example: “The functions, which determines the probability of a fisher returning home, depend on the number of hours after which 50 and 95% of fishers, respectively, will return home.” |
| 34 | Random utility | General considerations | “The probability that an agent chooses a site from all sites is depending on the expected utilities from each of those sites. The utility depends on including cost, expected catch rate, site attributes and angler characteristics.” |
| 35 | Random utility | General considerations | “The probability that an agent chooses a site from all sites is depending on the expected utilities from each of those sites. The utility depends on including cost, expected catch rate, site attributes and angler characteristics.” |

Table 6: Social subsystems - Social interaction

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ID** | **Interaction between agents** | **Information transfer between agents** | **Social network** | **Social network initialization** |
| 1 | Sharing recourses | None | Static | Random |
| 2 | Trading | None | Evolving | Random |
| 3 | None | None | None |  |
| 4 | None | None | None |  |
| 5 | None | Indirect (observing) | None |  |
| 6 | None | None | None |  |
| 7 | None | None | None |  |
| 8 | None | Direct (multiple) | None |  |
| 9 | None | None | None |  |
| 10 | None | None | None |  |
| 11 | None | None | None |  |
| 12 | None | Know everything | Static | Random |
| 13 | None | None | None |  |
| 14 | Trading | None | Evolving | Random |
| 15 | None | Direct (one thing) | None |  |
| 16 | None | Indirect (observing) | None |  |
| 17 | None | Indirect (observing) | None |  |
| 18 | None | Indirect (observing) | None |  |
| 19 | None | None | None |  |
| 20 | None | None | None |  |
| 21 | None | None | None |  |
| 22 | None | None | None |  |
| 23 | None | None | None |  |
| 24 | None | None | None |  |
| 25 | Trading | None | None |  |
| 26 | Interference | Indirect (observing) | Evolving | Manually |
| 27 | None | None | None |  |
| 28 | None | None | None |  |
| 29 | None | None | None |  |
| 30 | None | None | None |  |
| 31 | None | Indirect (observing) | None |  |
| 32 | None | None | None |  |
| 33 | None | None | None |  |
| 34 | None | None | None |  |
| 35 | None | None | None |  |

Table 7: Social subsystems - norms and adaptation

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **ID** | **Social**  **norms** | **Legal norms/**  **policies** | **Legal norms/ policies behavior** | **Legal norms/ policies types** | **Memory** | **Memory time-frame** | **Information types** | **Learning** |
| 1 | No | Multiple | Static | Input (fishing season), output (quotas) | None |  |  | No |
| 2 | Yes | None |  |  | Single | Long term | Social value | No |
| 3 | No | Single | Static | Other | Multiple | Long term | Fishing spots, catches | No |
| 4 | No | None |  |  | None |  |  | No |
| 5 | Yes | None |  |  | Multiple | Long term | Fishing spots, catches, economic outcomes | No |
| 6 | No | Single | Static | Input (fishing season) | Single | Long term | Economic outcomes | No |
| 7 | No | Multiple | Static | Input (fishing season), output (MLS) | None |  |  | No |
| 8 | No | Single | Static | Input (areas) | None |  |  | No |
| 9 | No | Single | Static | Input (areas) | None |  |  | No |
| 10 | No | Multiple | Static | Input (areas), output (quotas) | Single | Short term | Fishing spots | No |
| 11 | No | Single | Static | Input (areas) | None |  |  | No |
| 12 | No | Multiple | Dynamic | Input (areas, gear), output (quotas) | Single | Short term | Fishing spots | No |
| 13 | No | Single | Static | Output (MLS) | Single | Short term | Catches | No |
| 14 | Yes | None |  |  | Single | Long term | Social value | No |
| 15 | No | Single | Static | Output (MLS) | Multiple | Short term | Fishing spots, catches | No |
| 16 | No | Multiple | Dynamic | Input (fishing season), output (quotas) | Multiple | Long term | Fishing spots, catches | No |
| 17 | No | Multiple | Dynamic | Input (fishing season), output (quotas) | Multiple | Long term | Fishing spots, catches | No |
| 18 | No | None |  |  | Multiple | Long term | Fishing spots, catches | No |
| 19 | No | None |  |  | None |  |  | No |
| 20 | Yes | None |  |  | Multiple | Long term | Catches, economic outcomes | No |
| 21 | No | None |  |  | None |  |  | No |
| 22 | No | Multiple | Dynamic | Input (areas, gear), output (quotas) | Multiple | Long term | Fishing spots, other locations | No |
| 23 | No | Multiple | Static | Input (areas), output (quotas) | None |  |  | No |
| 24 | No | None |  |  | Single | Long term | Fishing spots | No |
| 25 | No | Single | Static | Output (quotas) | None |  |  | No |
| 26 | No | None |  |  | Multiple | Long term | Behavioral rules | Yes |
| 27 | No | Single | Static | Input (areas) | None |  |  | No |
| 28 | No | None |  |  | Single | Long term | Catches | No |
| 29 | No | None |  |  | Multiple | Long term | Fishing spots, catches | No |
| 30 | No | Single | Static | Output (MLS) | None |  |  | No |
| 31 | No | None |  |  | None |  |  | No |
| 32 | No | Single | Static | Input (areas) | None |  |  | No |
| 33 | No | Multiple | Static | Input (licenses), output  (MLS, Quotas) | Single | Long term | Fishing spots | No |
| 34 | No | Single | Static | Input (areas) | None |  |  | No |
| 35 | No | Single | Static | Input (areas) | None |  |  | No |

Table 8: Ecological subsystems, interaction social and ecological subsystems, implementation

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **ID** | **Temporal scale** | **Spatial scale** | **Decisions** | **Influence on environment** | **Environmental influence on decisions** | **Tool/ language** | **Temporal**  **resolution** |
| 1 | Years | Regional | Site choice, Port choice | None | Spatial aspects, spot information | R | Steps (1 d) |
| 2 | Decades | Regional | Chose fish buyer/fisher | Catch | None | NetLogo | Steps (1 d) |
| 3 | Decades | National | Effort, site choice, trip length | Catch | Fish stock feedback | NetLogo | Steps (1 d) |
| 4 | Decades | Regional | Site choice | Catch | Spatial aspects, spot information | ROMS (Regional Ocean Modeling System) | Steps (6 h) |
| 5 | Decades | National | Effort, site choice | Catch | Wind/weather, fish stock feedback | NetLogo | Steps (1 d) |
| 6 | Decades | None | Fishery entry/exit, investment, effort | Catch | Fish stock feedback | R | Steps (1 d) |
| 7 | Decades | Regional | Effort, site choice, trip length | Catch | Wind/weather, spatial aspects, fish stock feedback | Unknown | Unknown |
| 8 | Unknown | None | Site choice | Catch | Fish stock feedback | Unknown | Steps (Unknown) |
| 9 | Unknown | None | None | Catch | None | Python | Steps (Unknown) |
| 10 | Unknown | None | Site choice | Catch | Spatial aspects, fish stock feedback | MASON Library | Steps (1 d) |
| 11 | Days | Regional | Site choice | Catch | Wind/weather, spatial aspects, fish stock feedback | NetLogo | Steps (1 h) |
| 12 | Decades | None | Effort, gear type, site choice, trip length | Catch | Spatial aspects, fish stock feedback | MASON Library | Steps (1 d) |
| 13 | Decades | Local | Gear type | Catch | Fish stock feedback | Unknown | Steps (5 d) |
| 14 | Decades | Regional | Effort, chose fish buyer | Catch | None | NetLogo | Steps (1 d) |
| 15 | Decades | Local | Site choice | Catch | Spot information, fish stock feedback | R | Steps (1 min) |
| 16 | Months | Local | Effort, site choice | Catch | Water flow/current, fish stock feedback | Unknown | Steps (2.32 min) |
| 17 | Months | Local | Effort, site choice | Catch | Water flow/current, fish stock feedback | Unknown | Steps (2.32 min) |
| 18 | Months | Local | Effort, site choice | Catch | Fish stock feedback | Unknown | Unknown |
| 19 | Decades | Regional | Site choice | Catch | Spatial aspects, spot information | ROMS (Regional Ocean Modeling System) | Steps (900 s) |
| 20 | Decades | Regional | Investment, harvest | Catch | Fish stock feedback | NetLogo | Steps (1 d) |
| 21 | Decades | Regional | Site choice | Catch | Spatial aspects, spot information | ROMS (Regional Ocean Modeling System) | Steps (900 s) |
| 22 | Years | International | Port choice, site choice | Catch | Spatial aspects, fish stock feedback | C++ | Steps (1 h) |
| 23 | Years | Local | Effort, site choice | Catch | Spot information | Cormas | Steps (1 d) |
| 24 | Unknown | Regional | Site choice | None | Spatial aspects, fish stock feedback | Unknown | Steps (1 h) |
| 25 | Decades | Regional | Effort, quota trading, site choice | Catch | Spatial aspects, spot information | Unknown | Steps (1 month) |
| 26 | Decades | Local | Site choice | Catch | Spot information, seasonality, fish stock feedback | Unknown | Steps (1 d) |
| 27 | Unknown | None | Site choice | Catch | Spot information | Cormas | Steps (Unknown) |
| 28 | Decades | Regional | Site choice | Catch | Wind/weather, fish stock feedback | Python | Steps (1 week for env. & 1 month for  social) |
| 29 | Decades | Regional | Site choice | Catch | Fish stock feedback | Unknown | Steps (1 month) |
| 30 | Decades | Regional | Effort, harvest/release | Removals (harvest + death releases) | Fish stock feedback | NetLogo | Steps (1 week) |
| 31 | Days | Local | Site choice | Catch | Water flow/current | R | Steps (1 min) |
| 32 | Decades | Regional | Effort, trip timing, site choice, trip length | Catch | Spot information | Java with Repast simulation toolkit | Steps (1 d) |
| 33 | Unknown | Regional | Effort, trip timing, site choice, trip length | Catch | Fish stock feedback | Visual  Basic.Net | Discrete events |
| 34 | Decades | Regional | Effort, trip timing, site choice, trip length | Catch | Spot information | Java with Repast simulation toolkit | Steps (1 d) |
| 35 | Decades | Regional | Effort, trip timing, site choice, trip length | Catch | Spot information | Java with Repast simulation toolkit | Steps (1 d) |

Table 9: Credibility and reproducibility (part 1)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **ID** | **Documentation standard** | **Data**  **clarity** | **Data sources** | **Data accessibility** | **Purpose of data generation** | **Data usage** |
| 1 | None | All | National survey | Public & private | No | Micro as micro input/calibration & Macro as micro and  macro input/calibration and validation |
| 2 | ODD(+D) | All | Interviews, logbook,  literature, expert knowledge | Public & private | Yes | Micro as micro input/calibration & macro as macro input/calibration |
| 3 | None | All | Interviews, national survey, assumptions/ own estimates | Public & private | Yes | Micro as micro input/calibration & Macro as micro and macro input/calibration and validation |
| 4 | None | All | Literature, international surveys | Public | No | Micro as micro input/calibration & Macro as micro and macro input/calibration and validation |
| 5 | ODD(+D) | All | Literature, expert knowledge, assumptions/ own estimates | Public | No | Micro as micro input/calibration & Macro for validation |
| 6 | None | None | Assumptions/ own estimates,  Unknown | Unknown | Unknown | None |
| 7 | None | All | Local survey, logbook | Public & private | No | Micro as macro input/calibration & Macro as macro input/calibration and validation |
| 8 | None | Some | Literature | Public | No | Macro as micro input/calibration |
| 9 | None | None | Unknown | Unknown | Unknown | None |
| 10 | None | Some | Assumptions/ own estimates | Unknown | Yes | None |
| 11 | None | Some | International survey | Public | No | Macro as macro input/calibration |
| 12 | ODD(+D) | Some | Assumptions/ own estimates | Unknown | Yes | None |
| 13 | None | Some | Literature, interviews | Public | No | Micro as micro input/calibration |
| 14 | ODD(+D) | All | Expert knowledge, interviews, logbook, literature | Public & private | Yes | Micro as micro input/calibration & Macro as macro input/calibration |
| 15 | None | All | Local and national survey, expert knowledge,  literature | Public & private | No | Micro as micro input/calibration & Macro as macro input/calibration and validation |
| 16 | None | All | National and local surveys, mandatory reported fishery data | Public & private | No | Macro as macro input/calibration and validation |
| 17 | None | All | National and local surveys, mandatory reported fishery data | Public & private | No | Macro as macro input/calibration and validation |
| 18 | None | All | National and local surveys, mandatory reported fishery data | Public & private | No | Micro as macro input/calibration & Macro as micro and macro input/calibration and validation |
| 19 | None | All | Literature, international surveys, assumptions/own estimates | Public & private | No | Micro as micro input/calibration & Macro as micro and macro input/calibration and validation |
| 20 | None | All | Interviews, literature, national survey | Public & private | Yes | Micro as micro and macro input/calibration & Macro as macro input/calibration and validation |
| 21 | None | All | Literature, international surveys, assumptions/own estimates | Public & private | No | Micro as micro input/calibration & Macro as micro and macro input/calibration and validation |
| 22 | None | All | International surveys, logbook, literature | Public & private | No | Micro as micro input/calibration & Macro as micro and macro input/calibration and validation |
| 23 | None | Some | Interviews, observation, expert knowledge, literature | Public & private | Yes | Micro as micro input/calibration & Macro as macro input/calibration and validation |
| 24 | None | Some | Logbook | Private | No | Micro as micro input/calibration |
| 25 | None | Some | National survey, interviews, voluntary & compulsory logbook | Private | Yes | Micro as micro and macro input/calibration & Macro as macro input/calibration and validation |
| 26 | None | Some | National survey, logbook | Private | No | Micro as macro input/calibration & Macro for validation |
| 27 | None | None | Unknown | Unknown | No | None |
| 28 | None | Some | Local and national survey, expert knowledge, stakeholder knowledge | Private | No | Macro as macro input/calibration and validation |
| 29 | None | Some | Unknown | Unknown | Unknown | Macro as macro input/calibration and validation |
| 30 | ODD(+D) | All | National survey, literature | Public & private | No | Macro as micro and macro input/calibration |
| 31 | None | All | Local survey, interviews, literature | Public & private | No | Micro as micro input/calibration & Macro as micro input/calibration |
| 32 | None | All | National survey, literature | Public & private | No | Micro as micro input/calibration & Macro for validation |
| 33 | ODD(+D) | Some | Interviews | Public & private | Yes | Micro as micro input/calibration & Macro as macro input/calibration |
| 34 | None | All | National survey, literature | Public & private | No | Micro as micro input/calibration |
| 35 | None | All | National survey, literature | Public & private | No | Micro as micro input/calibration |

Table 10: Credibility and reproducibility (part 2)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **ID** | **code availability** | **Input parameter clarity** | **Assumptions specified** | **Limitations specified** | **Calibration** | **Validation** | **Sensitivity analysis** |
| 1 | Model & experiments | Some | Yes | Yes | Described | None | Available |
| 2 | Model & experiments | All | Yes | Yes | Available | Available | Available |
| 3 | None | All | Yes | Yes | Available | Available | Available |
| 4 | None | All | Yes | Yes | Available | Available | Available |
| 5 | Model & experiments | All | Yes | Yes | None | Available | Available |
| 6 | None | All | Some | Some | Available | Available | None |
| 7 | None | All | Yes | Yes | Available | None | Available |
| 8 | None | All | Some | Some | Available | Mentioned | Mentioned |
| 9 | None | All | Yes | Yes | None | None | None |
| 10 | None | All | Some | Some | None | None | Available |
| 11 | None | All | Some | Some | Mentioned | None | None |
| 12 | None | All | Some | Some | Described | None | Available |
| 13 | None | All | Yes | Yes | None | None | None |
| 14 | Model & experiments | All | Yes | Yes | Available | Available | Available |
| 15 | None | All | Yes | Yes | None | Available | Available |
| 16 | Model & experiments | All | Yes | Yes | Mentioned | None | Available |
| 17 | Model & experiments | All | Yes | Yes | Mentioned | None | Available |
| 18 | None | None | Some | Some | Described | None | Available |
| 19 | None | All | Yes | Yes | Available | Available | Available |
| 20 | None | All | Yes | Yes | Available | None | Available |
| 21 | None | All | Yes | Yes | Available | Available | Available |
| 22 | None | Some | Yes | Yes | None | Mentioned | Available |
| 23 | Model & experiments | Some | Some | Some | Mentioned | Described | Available |
| 24 | None | None | No | No | None | None | None |
| 25 | None | Some | Yes | Yes | None | None | Available |
| 26 | None | Some | Yes | Yes | Available | None | Available |
| 27 | None | Some | Some | Some | Mentioned | None | None |
| 28 | None | Some | Some | Some | None | None | Available |
| 29 | None | Some | Some | Some | None | Mentioned | Available |
| 30 | Model | All | Yes | Yes | Available | Available | None |
| 31 | None | All | Yes | Yes | Available | None | Available |
| 32 | None | Some | Some | Some | None | Described | Available |
| 33 | None | All | Yes | Yes | Available | None | None |
| 34 | None | Some | Some | Some | None | None | None |
| 35 | None | Some | Some | Some | None | None | None |

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