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MODELLING AND DECISION MAKING AS PART OF THE CCAMLR MANAGEMENT REGIME

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Abstract

This paper outlines a stylised scheme designed to address the multi-objective decision environment essential for the effective management of the Antarctic marine ecosystem within the requirements of CCAMLR Article II. Eight attributes (purpose, description, variables, driving forces, time horizons, time steps, constraints and data) were identified in an attempt to provide a blueprint for the development of suitable simulations of important Antarctic marine ecosystem interactions and to facilitate the formulation of a suitable decision-making protocol for management purposes.

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MODELE ET PRISE DE DECISIONS DANS LE CADRE DU REGIME D'AMENAGEMENT DE LA CCAMLR

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Résumé

Le présent document expose les grandes lignes d'un plan stylisé dont le but est de mettre au point le système de prise de décisions à objectifs multiples nécessaire à l'aménagement efficace de l'écosystème marin de l'Antarctique conformément aux conditions de l'Article II de la CCAMLR. Huit attributs ont été identifiés (but, description, variables, motivations, limites temporelles, étapes temporelles, restrictions et données) dans le but de fournir un schéma directeur pour le développement de simulations appropriées des interactions importantes de l'écosystème marin de l'Antarctique et pour faciliter la formulation d'un protocole approprié à la prise de décisions à des fins d'aménagement.

Note: Les tableaux de ce document ont été traduits et figurent intégralement à la fin de l'article.

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MODELADO Y TOMA DE DECISIONES COMO PARTE DEL REGIMEN DE ADMINISTRACION DE LA CCRVMA

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Resumen

Este documento describe un esquema estilizado que ha sido diseñado para orientar la toma de decisiones con respecto a una serie de objetivos, esencial para la administración efectiva del ecosistema marino antártico, hacia los requisitos del Artículo II de la CCRVMA. Se han identificado ocho secciones (propósito, descripción, variables, fuerzas de empuje, límites de tiempo, etapas de tiempo, limitaciones y datos) con la intención de proveer una base para el desarrollo de simulaciones apropiadas de las interacciones importantes del ecosistema marino antártico y para facilitar la preparación de un protocolo para la toma de decisiones con fines administrativos.

Nota: Las tablas en este documento han sido traducidas y son presentadas en forma completa al final del artículo.

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МОДЕЛИРОВАНИЕ И ПРИНЯТИЕ РЕШЕНИЙ: КОМПОНЕНТЫ РЕЖИМА УПРАВЛЕНИЯ АНТКОМ'а

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Резюме

В настоящем документе кратко описывается стилизованная схема, задуманная для создания комплексной системы принятия решений, необходимой для эффективного управления морской экосистемой Антарктики в рамках Статьи II Конвенции. Было выделено восемь критериев (назначение, описание, переменные, движущие силы, сроки, продолжительность этапов, ограничения и данные) как попытка представить наметку плана разработки подходящих моделей важных взаимодействий в морской экосистеме Антарктики и способствовать выработке подходящего порядка принятия решений по вопросам управления.

Примечание: Таблицы, содержащиеся в настоящей работе, были переведены и приводятся полностью в конце статьи.

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MODELLING AND DECISION MAKING AS PART OF THE CCAMLR MANAGEMENT REGIME

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INTRODUCTION

Various authors (e.g. Beddington and de la Mare 1984; Sissenwine 1984; Butterworth 1986) have recognised that to achieve the objectives of CCAMLR Article II requires the development of a suitable suite of multi-species models for the Antarctic marine ecosystem as a whole (or at least for some geographically isolated component of the system). As is the case with many other system models currently available, simulations of Antarctic marine ecosystem interactions (e.g. May et al 1979; Beddington 1980; Beddington and May 1980; Green-Hammond 1981; Nagata 1983; Yamanaka 1983) do, to a greater or lesser degree, improve understanding of the system's dynamics. While accepting the critical need for further development of models of this kind, it must be appreciated that such models generally appear to have been used less or to have been less useful in the decision-making process associated with managing renewable fisheries resources (Shelton et al 1984). In some fisheries, managers may even have been misled into holding unrealistic expectations with respect to the predictive capabilities of multi-component models, which have in practice performed badly, or worse, been misleading. This may have resulted in some managers developing a model-averse perspective which, in turn, has effected a return to the use of the less objective tools of intuition, experience and rules of thumb in formulating management recommendations on renewable resources. The potential for over-dependence on such less objective procedures is particularly serious with respect to implementation of CCAMLR Article II since there is an appreciable dearth of information on important Antarctic marine ecosystem interactions.

As Starfield et al (1986) have indicated, part of the reason why modelling has not been used more in the decision-making process may be that modellers of both terrestrial and marine systems have tended to become locked into the idea of using a single model. In general, fisheries scientists have concentrated on relatively small, less complex models where emphasis has come to be placed on improved statistical parameter estimation procedures (e.g. Deriso 1980). The result has been that decision-makers find that whole system models are too large and imprecise to deal with specific problems while fisheries models are too small and narrowly focused to provide solutions to more general problems.

For the Antarctic marine ecosystem, it appears inevitable that no single model will be flexible enough to address the wide range of potential problems which constitute the decision-making environment for managers of renewable resources in terms of CCAMLR Article II. In keeping with the ideas put forward by Starfield et al (1986) it is proposed that development of a suite of CCAMLR management protocols requires access to a number of model output scenarios. As such, a "toolbox" of models needs to be developed and such models could then be used to bring a variety of insights to bear on a particular problem. Conversely, the same model could be used in various ways to find solutions to different problems. This approach can be illustrated within the context of the ecosystem perspective advocated by CCAMLR.

THE ANTARCTIC MARINE ECOSYSTEM

The Antarctic marine ecosystem is essentially dominated in the pelagic zone by krill (Euphausia superba) (Everson 1977 and others). This species forms large concentrations which are a source of food for a number of important predators (including whales, seals, penguins, fish and various seabirds) and may become the focus of substantial fisheries activities.

At present no coherent management plan has yet been formulated for the system briefly outlined above. Nevertheless, the principles outlined in Article II of the Convention stress the need to conserve the ecosystem as a whole (Edwards and Heap 1981). The principal management objective for any fisheries activities can thus be considered (within the principles of Article II) to ensure that the fisheries industries (both fishing activity and consumer demand) is reasonably stable over some given period of time while ensuring the restoration of populations depleted in the past and precluding the disruption of ecosystem functioning. In these terms, Article II enunciates a multiplicity of objectives, thereby suggesting that it would be inappropriate to use a single "best" model for decision-making. The question to be asked therefore is "What modelling approaches are likely to be applicable in terms of implementing the Convention?". It can thus be argued that to answer this question it is first necessary to develop an overall framework or scheme within which to structure the decision environment.

The scope of any particular model in a multi-objective decision environment could vary widely and several alternatives are possible (Table 1). For example, socio-economic considerations could be incorporated under the heading of "Industry and fish" and ecosystem considerations could be divided into lower categories, those concerned with interactions at the same trophic level (such as competition) and those including interactions between different trophic levels such as predation by birds or seals on krill. This division is essential since the same models would not necessarily be applicable for both isotrophic and multitrophic factors. In terms of CCAMLR, it is necessary to specifically consider predators in view of the requirements in Article II for restoring depleted populations (particularly whales).

Within each suggested scope, it can be anticipated that the objectives of specific modelling exercises could be radically different. For this reason, three objective rows are included in Table 1. "Ecological objectives" are concerned solely with system objectives, whereas economic and social objectives would also consider resource utilization. For example, Cell A of Table 1 would include consideration of intraspecific or environmental influences on the relationship between stock and recruitment, whereas Cell E might examine the risks associated with various harvesting strategies. The third grouping (or combination of management research and monitoring of objectives) in Cell K would address the question as to what research or marketing should be conducted to elucidate predator-prey interactions.

MODELS TO FIT THE SCHEME : SOME EXAMPLES

The model construction scheme outlined above is similar to that originally constructed by Starfield et al (1986) for the Benguela Current system. In order to assist in building a collection of models for use within the 12 decision-making scenarios proposed, it is possible to identify 8 attributes so forming a "blue print" for various models that may be considered to describe the Antarctic marine ecosystem. The attributes described were developed from a general consideration of modelling procedures outlined by Starfield and Bleloch (1986) rather than from an examination of any existing model. They are comprised of purpose, description, variables, driving forces, time horizon, time step, constraints and data.

The purpose of a model refers to the specific reason for the model's use. The description encompasses the type of model (e.g. speculative simulation model or predictive model) being used. The outputs of the model are the quantitative or qualitative changes in values of dependent variables in response to driving forces which are the independent variables or parameters which force the behaviour of the modelled system. The time horizon is the period over which the behaviour of the variables is assessed, and the time step is the incremental period within the model. The constraints are the bounds imposed on the behaviour or the interpretation of the model (e.g. limitations of the data), and the data are the items of information upon which the model is structured.

The characterisation of such a model by means of its attributes is best illustrated by way of an example. First, a model is proposed which has yet to be developed for krill (i.e. a renewable and potential fisheries resource) and then some attempt is made to fit existing models or model types into the scheme.

When exploring decisions in the context of predators, (e.g. crabeater seals) and their prey (i.e. krill) in relation to ecological objectives (Cell C, Table 1), three models each with different purposes may be identified (Table 2). The first of these models (3A-Table 2) would be for the purpose of providing insights into predator population control measures which may be required to prevent expansion of the selected predator population. This model prescribes a speculative simulation which is structured as a single-species population model and for which the main variable is predator biomass. It is noted that detailed age and distributional structure are required for the model, although minimal age structure should be used in the interests of simplicity. The performance of control measures would be assessed by examining changes in predator biomass in response to the driving forces of prey (krill) biomass and predator (seal) harvests. A time horizon of 5 years is considered appropriate, with time steps of one year being adequate, or less than one year if seasonal influences need to be considered. The constraints of such a model are that they are likely to be limited by the availability of data, the data requirements (including predator population sizes, dynamics, food consumption rates and diet) and in the case of a spatial model, patterns of predator distribution.

The purpose of the second model (3B) would be to provide insight into methods of containing predator (e.g. crabeater seal) population size, for example in order to rebuild some other predator (e.g. whales) population to an acceptable proportion of a former (i.e. pre-depleted) level. In this case, a speculative predator-prey model would be appropriate in which the driving forces would be the synchronous harvesting of predators and prey alike - the third model (3C) would be required to explore causal factors determining the relative abundance of predators in the system. This would be directly relevant to the performance of the joint exploitation of several co-existing predators (e.g. seals and penguins), the abundance of which may be influenced directly by exploitation, or by competition for resources which are themselves harvested (e.g. krill). A multispecies predator model would therefore be required and, as with model 3B, the driving forces would be the harvests of the predators and their prey. Each of the models in Table 2 would probably be constrained by limitations of data.

The above three models address decisions within only one of 12 decision scenarios in the modelling schema. Filling the entire schema forces an explicit statement of the levels of understanding of the system being considered. Existing models can therefore be viewed in relation to the entire suite of models considered appropriate for the range of potential decision scenarios in renewable resource management.

In the Antarctic, at least seven models would be applicable to schema described above. These are listed with their purposes in abbreviated form in Table 3. A feature of the modelling schema is that individual models may be used within more than one decision scenario (Starfield et al 1986) - an example being the stochastic risk evaluation model (Cells E and I). This model could involve a Monte Carlo simulation incorporating levels of uncertainty in biomass estimates and population parameters of the krill resource in order to calculate the mean and variance of the catch which meets a specified harvest strategy target. In Cell E the model can be used to evaluate any trade-off between the level of yield and the risk of stock collapse. In Cell I, the same model could be used to assess the contribution of improved precision in measurements of biomass and population parameters to reduction of the variance of estimated potential yield, thereby identifying the areas where direction of research effort would be most profitable.

DISCUSSION

It is relatively easy to construct a complex simulation if one is confident of both the relationships that constitute the simulation and key parameter values. A complex multi-species, ecosystem model, capable of addressing all, or most, of the requirements of CCAMLR Article II is inconceivable given the general lack of understanding of the various inter-relationships and of critical data.

How then does one begin the process of constructing useful models when understanding and data are so limited? Under such conditions, a model can only really be effective if it is carefully focused, parsimonious and decision-driven. The main advantage of the present schema is that it provides the setting for a suite of small, well-defined models. By categorising the purpose and context of each model scenario, it enables us to design an appropriate holistic model suite.

For example, an all-purpose model relating to both predators and prey would have to contain an explicit algorithm for prey selection and the mutual interactions of predators and their prey (Butterworth 1984). At present, both the structure and parameter values in that algorithm would be sheer guesswork. However, if the purpose of the model is to compare various strategies for controlling a selected predator population, there is no real need to have both predators and prey as variables in the model - prey availability can in fact be considered as an input to a complementary predator population model (i.e. a driving force). Conversely, if the purpose is to explore possible conflict between the demands of predation and commercial fishing of a selected prey species, predator populations need not be simulated but can be considered as input for a population or harvesting model. If, however, the purpose of the model is to formulate a strategy for harvesting both predators and prey, then their mutual interaction is crucial. Since that interaction would essentially not be understood, the rest of the model should therefore be simplified as much as possible in order to allow speculation on the effects of different predator-prey interactions on the harvest.

The schema presented here is not necessarily the best that could be devised for the Antarctic marine ecosystem. The point is that such a schema encourages productive thought about models that are needed and shows to some degree how these may be designed. Preparation of a schema of this sort also has a number of important side-effects :

(a) It encourages consideration of the Antarctic marine ecosystem from a broad perspective (instead of concentrating on available models, it encourages consideration of what models are actually required). In this process it raises questions that might not normally be asked. For example, discussion about the third row of the schema (Table 1) is likely to question when and how management decisions are taken, the cost-effectiveness of research and monitoring and how best to spend a monitoring budget.

(b) The schema facilitates explanations to the Commission level. Showing where a particular model fits and arguing why it is of necessity speculative (or adaptive or productive) helps to develop more realistic expectations of modelling.

(c) The schema highlights how the same model could be used in different ways and also how different models may sometimes be required to address questions that are superficially similar.

(d) It follows that the schema could be expected to result in a suite of models combined with a decision support system (e.g. Rykiel et al 1984) which guides the user, depending on his purpose, or perhaps suggests how results from different models might be combined. Such a suite or "toolbox of models" could even contain complex multi-species models. Its purpose would be to provide a simulated "world" to test the effectiveness of some of the more specific empirical models that are likely to be or have been developed. This would be directly applicable with respect to Cells I-L in the schema presented in Table 1.

Just as the schema may not be optimal, so the attributes in Table 2 may not necessarily be the best. As such, the purpose is to show how such a schema can provoke thought about what model attributes to use and to ask questions about appropriate time scales and the choice of variables etc. Since the schema forces potential simulations of Antarctic marine ecosystem dynamics and interactions to consider both the questions being addressed and the available data, it should promote the design and the use of suitable models for management purposes.

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Table 1. Decision making schema.

SCOPE OBJECTIVE	Single species	Isotrophic multi-species	Predators and prey	Industry and fish
Ecological	A	B	C	D
Economic and social	E	F	G	H
Management monitoring & research	I	J	K	L

Table 2. Attributes for three models appropriate to Cell C of the decision-making schema illustrated in Table 1.

MODEL 3A	
PURPOSE	To provide insight into predator population control measures.
DESCRIPTION	Speculative single species predator simulation model.
VARIABLES	Predator biomass.
DRIVING FORCES	Prey biomass and fishing.
TIME HORIZON	5 years.
TIME STEPS	1 year unless there is a seasonal influence on the population.
CONSTRAINTS	Data limited.
DATA	Predator population sizes and dynamics, consumption rates, diet analysis.
MODEL 3B	
PURPOSE	To provide insight into predator population enhancement.
DESCRIPTION	Speculative single species predator-prey simulation model.
VARIABLES	Predator and prey biomass.
DRIVING FORCES	Harvest of predators and prey.
TIME HORIZON	5 years.
TIME STEPS	1 year unless there is a seasonal influence on the population.
CONSTRAINTS	Data limited.
DATA	Predator and prey population sizes and dynamics, predator consumption rates and diet analysis.

MODEL 3C	
PURPOSE	To explore possible mechanisms influencing the abundance of predators in the system.
DESCRIPTION	Speculative multi-species predator simulation model.
VARIABLES	Predator biomass.
DRIVING FORCES	Prey biomasses and harvesting.
TIME HORIZON	5 years.
TIME STEPS	1 year unless there is a seasonal influence on the population.
CONSTRAINTS	Data limited.
DATA	Predator population sizes and dynamics, consumption rates, diet analysis.

Table 3. Potentially useful models of the Antarctic krill resource and where they might be fitted into the proposed management decision schema. The cells refer to Table 1.

MODEL	CELL	PURPOSE	DESCRIPTION
Yield-per-recruit model	E	Estimation of desirable levels of fishing	Deterministic, speculative, age-structured simulation model.
Stochastic risk evaluation model	E,I	Estimation of potential krill yields under conditions of uncertainty of key paramaters.	Stochastic, age-structured Monte Carlo simulation model.
Krill population simulation model	E,I	Assessment of alternative harvest strategies.	Stochastic, speculative age-structured model with economics subroutine.
Multi-species catch-effort model	F	Estimation of combined species yield.	Predictive regression-based model.
One predator, two prey model	C	Exploration of predator-prey dynamics	Speculative simulation model.
Fishery dynamics model	B,F	Examination of species replacement in the catches.	Speculative simulation model.
Linear optimisation model	E	Estimation of economically optimum combined species yields.	Linear programme.

Tableau 1. Schéma de prise de décisions

OBJECTIF	Espèces simples	Espèces multiples isotrophiques	Prédateurs et proies	Industrie et poissons
Ecologique	A	B	C	D
Economique et social	E	F	G	H
Aménagement contrôle et recherche	I	J	K	L

Tableau 2. Attributs pour trois modèles appropriés à la cellule c du schéma relatif à la prise de décisions illustré au Tableau 1.

MODELE 3A	
BUT	Permettre de comprendre les mesures de contrôle démographique des prédateurs.
DESCRIPTION	Modèle spéculatif de simulation à espèce unique de prédateurs.
VARIABLES	Biomasse des prédateurs.
MOTIVATIONS	Biomasse des proies et pêche.
PERIODE LIMITE	5 ans.
ETAPES TEMPORELLES	1 an à moins que la populatgion ne soit soumise à une influence saisonnière.
RESTRICTIONS	Données limitées.
DONNEES	Tailles et dynamique des populations de prédateurs, taux de consommation et analyse du régime alimentaire.
MODELE 3B	
BUT	Permettre de comprendre l'accroissement démographique des prédateurs.
DESCRIPTION	Modèle spéculatif de simulation á espèce unique de prédateurs-proies.
VARIABLES	Biomasse des prédateurs et proies.
MOTIVATIONS	Capture des prédateurs et proies.
PERIODE LIMITE	5 ans.
ETAPES TEMPORELLES	1 an à moins que la population ne soit soumise à une influence saisonnière.
RESTRICTIONS	Données limitées.
DONNEES	Tailles et dynamique des populations de prédateurs et de proies, taux de consommation et analyse du régime alimentaire des prédateurs.

MODELE 3C	
BUT	Explorer les mécanismes éventuels influençant l'abondance des prédateurs dans le système.
DESCRIPTION	Modèle spéculatif de simulation à espéces multiples de prédateurs.
VARIABLES	Biomasse des prédateurs.
MOTIVATIONS	Biomasses des proies et capture.
PERIODE LIMITE	5 ans.
ETAPES TEMPORELLES	1 an à moins que la population ne soit soumise à une influence saisonnière.
RESTRICTIONS	Données limitées.
DONNEES	Tailles et dynamique des populations de prédateurs, taux de consommation et analyse du régime alimentaire.

Tableau 3. Modèles potentiellement utiles des ressources de krill antarctique et comment les incorporer dans le schéma de prise de décisions sur l'aménagement. Les cellules se rapportent au Tableau 1.

MODELE	CELLULE	BUT	DESCRIPTION
Modèle du rendement par recrue	E	Estimation des niveaux souhaitables de pêche	Modèle de simulation déterministe, spéculatif et par structures d'âge
Modèle d'évaluation du risque stochastique	E,I	Estimation des rendements potentiels du krill dans des conditions d'incertitude des paramètres clés	Modèle de simulation stochastique et par structures d'âge Monte Carlo
Modèle de simulation de la population de krill	E,I	Evaluation d'autres stratégies de capture	Modèle spéculatif et stochastique par structures d'âge avec une sous-programme economique
Modèle à espèces multiples de prise et d'effort	F	Estimation du rendement des espèces combinées	Modèle de prédictions basé sur la régression
Modèle -un prédateur, deux proies	C	Etude de la dynamique prédateur-proie	Modèle spéculatif de simulation
Modèle de la dynamique de la pêche	B,F	Examen du remplacement d'espèces dans les prises	Modèle spéculatif de simulation
Modèle d'optimisation linéaire	E	Estimation des rendements d'espèces combinées maximum du point de vue économique	Programme linéaire

Tabla 1 Esquema de toma de decisiones.

CAMPO DE OBJETIVOS	Especies individuales	Multiespecies isotróficas	Depredador y presa	Industria y peces
Ecológico	A	B	C	D
Económico y Social	E	F	G	M
Control de Administración e Investigación	I	J	K	L

Tabla 2. Secciones de tres modelos correspondientes a la Célula C del esquema de toma de decisiones, ilustrado en la Tabla 1.

MODELO 3A	
PROPOSITO	Proporcionar una percepción clara sobre las medidas de control de las poblaciones de depredadores.
DESCRIPCION	Modelo teórico monoespecífico de simulación de depredadores.
VARIABLES	Biomasa de depredadores.
FUERZAS DE EMPUJE	Biomasa de depredadores y pesca.
LIMITE DE TIEMPO	5 años.
ETAPAS DE TIEMPO	1 año a menos que haya una influencia estacional sobre las reservas.
LIMITACIONES	Datos limitados
DATOS	Tamaño y dinámica de las poblaciones de depredadores, índices de consumo, análisis de la dieta.
MODELO 3B	
PROPOSITO	Proporcionar una percepción clara sobre el aumento de las poblaciones de depredadores.
DESCRIPCION	Modelo teórico monoespecífico de simulación de depredadores-presa.
VARIABLES	Biomasa de depredador-presa.
FUERZAS DE EMPUJE	Recolección de depredador y presa.
LIMITE DE TIEMPO	5 años.
ETAPAS DE TIEMPO	1 año a menos que haya una influencia estacional sobre las poblaciones.
LIMITACIONES	Datos limitados.
DATOS	Tamaño y dinámica de las poblaciones de depredadores, índices de consumo de depredador y análisis de la dieta.

MODELO 3C	
PROPOSITO	Investigar los posibles mecanismos que influencian la abundancia de los depredadores en el sistema.
DESCRIPCION	Modelo teórico multi-especifico de simulación de depredadores.
VARIABLES	Biomasa de depredadores.
FUERZAS DE EMPUJE	Biomasas de depredadores y recolección.
LIMITE DE TIEMPO	5 años.
ETAPAS DE TIEMPO	1 año a menos que haya una influencia estacional sobre la reserva.
LIMITACIONES	Datos limitados.
DATOS	Tamaño y dinámica de las reservas de depredadores, índices de consumo, análisis de la dieta.

<u>Tabla 3</u> Modelos de recurso de krill antártico de posible utilidad y dónde podrían ubicarse en el propuesto esquema de decisiones administrativas. Las células se refieren a la Tabla 1.

MODELO	CELULA	PROPOSITO	DESCRIPCION
Modelo de rendimiento por restablecimiento	E	Cálculo de los niveles deseables de pesca estructurado por edad	Modelo de simulación determinativo, teórico y
Modelo de evaluación de riesgo de reservas	E, I	Cálculo de los los posibles rendimientos de krill bajo condiciones de incertidumbre con respecto a los parámetros claves	Modelo de simulación Monte Carlo, de reservas y estructurado por edad
Modelo de simulación de la población de krill	E, I	Evaluación de estrategias alternativas de recolección	Modelo teórico de reservas, estructurado por edad, con una subrutina de economía
Modelo multi-específico de captura y escuerzo	F	Cálculo de rendimiento de especies combinadas	Modelo de predicción basado en la regresión
Modelo de un depredador, dos presas	C	Exploración de la dinámica de depredador-presa	Modelo de simulación especulativo
Modelo de la dinámica de la pesca	B. F	Examinación del reemplazo de las especies en las capturas	Modelo de simulación especulativo
Modelo de optimización linear	E	Cálculo de los rendimientos de especies combinadas economicamente óptimos	Programa linear

Таблица 1. Схема принятия решений.

РАМКИ / ЦЕЛЬ	Одновидовая модель	Изотрофическая многовидовая модель	Хищники и жертва	Промысел и рыба
Экологические вопросы	A	B	C	D
Экономические и социальные вопросы	E	F	G	H
Вопросы управления, мониторинга и исследований	I	J	K	L

Таблица 2. Критерии трех моделей, соответствующих элементу "С" схемы принятия решений, приведенной в Таблице 1.

МОДЕЛЬ 3A

НАЗНАЧЕНИЕ	Дать понимание сущности мер по контролю над популяциями хищников.
ОПИСАНИЕ	Гипотетическая одновидовая модель, имитирующая популяцию хищников
ПЕРЕМЕННЫЕ	Биомасса популяции хищников
ДВИЖУЩИЕ СИЛЫ	Биомасса популяции жертв и промысел
СРОКИ	5 лет
ПРОДОЛЖИТЕЛЬНОСТЬ ЭТАПОВ	1 год, если только не наблюдается сезонных воздействий на популяцию.
ОГРАНИЧЕНИЯ	Ограниченное количество данных
ДАННЫЕ	Размеры и динамика популяции хищников, уровень потребления, анализ режима питания.

МОДЕЛЬ 3B

НАЗНАЧЕНИЕ	Дать понимание процесса увеличения популяций хищников
ОПИСАНИЕ	Гипотетическая одновидовая модель, имитирующая взаимодействие хищник-жертва
ПЕРЕМЕННЫЕ	Биомасса популяции хищников и жертв
ДВИЖУЩИЕ СИЛЫ	Вылов хищников и жертв
СРОКИ	5 лет
ПРОДОЛЖИТЕЛЬНОСТЬ ЭТАПОВ	1 год, если только не наблюдается сезонных воздействий на популяцию
ОГРАНИЧЕНИЯ	Ограниченное количество данных
ДАННЫЕ	Размеры и динамика популяций хищников и жертвы, уровни потребления и анализ режима питания хищников

МОДЕЛЬ 3С

НАЗНАЧЕНИЕ	Исследовать возможные механизмы, влияющие на численность хищников в системе
ОПИСАНИЕ	Гипотетическая многовидовая модель, имитирующая популяции хищников
ПЕРЕМЕННЫЕ	Биомасса популяций хищников
ДВИЖУЩИЕ СИЛЫ	Биомасса жертвы и облов
СРОКИ	5 лет
ПРОДОЛЖИТЕЛЬНОСТЬ ЭТАПОВ	1 год, если только не наблюдается сезонных воздействий на популяции
ОГРАНИЧЕНИЯ	Ограниченное количество данных
ДАННЫЕ	Размеры и динамика популяций хищников, уровень потребления, анализ режима питания.

Таблица 3. Потенциально полезные модели запаса антарктического криля и их возможное место в предлагаемой схеме принятия решений по управлению. Элементы схемы - как указано в Таблице 1.

МОДЕЛЬ	ЭЛЕМЕНТ	НАЗНАЧЕНИЕ	ОПИСАНИЕ
Модель улова на единицу пополнения	E	Расчет желательных уровней промысла	Детерминистическая гипотетическая имитационная модель, построенная по возрастным показателям
Стохастическая модель оценки опасности	E,I	Расчет потенциальной величины вылова криля при наличии неопределенности в ключевых параметрах	Стохастическая имитационная модель "Монте-Карло", построенная по возрастным показателям
Имитационная модель популяции криля	E,I	Оценка альтернативных стратегий лова	Стохастическая гипотетическая модель, построенная по возрастным показателям, с экономической подпрограммой
Многовидовая модель зависимости улов-усилия	F	Расчет величины вылова связанных видов	Прогнозирующая модель возврата к прежнему состоянию
Модель взаимодействия один вид хищников-два вида жертв	C	Исследование динамики взаимодействия хищник-жертва	Гипотетическая имитационная модель
Модель динамики промысла	B,F	Изучение замещения видов в уловах	Гипотетическая имитационная модель
Модель линейной оптимизации	E	Рост экономически оптимельных уровней вылова связанных видов	Линейная программа