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Selection of Externality Management Instruments in Marine Fisheries using Decision Support Software

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Abstract

New Zealand marine fishing activities create many types of environmental externalities, which by law must be internalised. Selection of best internalisation instruments can be aided by following a hierarchical decision process, which first screens the universe of instruments against implementation criteria to establish the feasible set. Instruments in the feasible set can be evaluated against a range of environmental, Treaty of Waitangi, economic, socio-cultural and management criteria. This approach to selection can be formalised in decision support software to provide a useful tool for fisheries management agencies.

1. Introduction

New Zealand has the fourth largest exclusive economic zone in the world. New Zealand was amongst the first countries to introduce individual property rights-based management on a universal basis when, in 1986, the Quota Management System (QMS) was introduced to promote sustainable management of fishery resources. Even though the individual transferable quota system (ITQ) has been successful in a number of respects, one of the growing concerns during the last decade is environmental externalities associated with the activities of commercial fishing. Such concerns have led to a wider focus on the need for sustainable management of the marine environment within the exclusive economic zone. This is reflected in the purpose and principles of the Fisheries Act 1996 (Figure 1). The purpose of the Act is to "provide for the utilisation of the resource while ensuring sustainability" and this requires that any adverse effects of fishing on the aquatic environment are avoided, remedied or mitigated.

Figure 1. Purpose and principles of the Fisheries Act 1996.

PART II: PURPOSE AND PRINCIPLES

8. Purpose – (1) the purpose of this Act is to provide for the utilisation of fisheries resources while ensuring sustainability.

(2) In this Act-

"Ensuring sustainability" means-

(a) Maintaining the potential of fisheries resources to meet the reasonable foreseeable needs of future generations; and

(b) Avoiding, remedying, or mitigating any adverse effects of fishing on the aquatic environment:

"Utilisation" means conserving, using, enhancing, and developing fisheries resources to enable people to provide for their social, economic, and cultural well-being.

9. Environmental principles – All persons exercising or performing functions, duties, or powers under this Act, in relation to the utilisation of fisheries resources or ensuring sustainability, shall take into account the following environmental principles:

(a) Associated or dependent species should be maintained above a level that ensures their long-term viability.

(b) Biological diversity of the aquatic environment should be maintained.

(c) Habitat of particular significance for fisheries management should be protected.

10. Information principles – All persons exercising or performing functions, duties, or powers under this Act, in relation to the utilisation of fisheries resources or ensuring sustainability, shall take into

account the following information principles:

(a) Decisions should be based on the best available information:

(b) Decision makers should consider any uncertainty in the information available in any case:

(c) Decision makers should be cautious when information is uncertain, unreliable, or inadequate:

The absence of, or any uncertainty in, any information should not be used as a reason for postponing or failing to take any measure to achieve the purpose of this Act.

Environmental externalities from fishing comprise a range of diverse events: marine pollution from ship's discharges; bycatch of non-target fish species; damage and mortality to non-fish species; and destruction of fish habitat. Hughey, Cullen, Kerr, Memon, Robb (2000) identified the New Zealand fisheries in which 'significant' externalities occur as:

- Any bottom dredging fishery on a non silt/sand substrate, eg. for oyster and scallop;
- Any bottom trawl fishery on a non silt/sand substrate, eg. for snapper and orange roughy;
- Long line fisheries where there is the presence of non-target fish species or seabirds in high numbers at the same fishing water level, e.g. tuna;
- Mid-water trawl fisheries where marine mammals occur in 'significant' numbers, e.g. Hooker sealions in southern squid fisheries; and
- Gillnet fisheries for eg. rig, other small sharks, and kahawai, where dolphins are present.

Generally, externalities can only be reduced at some cost and there is an economically optimal level of externality reduction where the marginal cost of externality reduction equals the marginal benefit from externality reduction (Pearce and Turner 1990) . Internalisation occurs when institutional change causes formerly external costs associated with fishing to be borne by the firm creating the externality. A key point is that fishers' behaviours or their fishing-related activities must change in order to avoid, remedy, or mitigate externalities. This can occur if the firms creating the external costs take any of the actions listed below, resulting in reduced incidence of the externality creating behaviour:

- Reduce, stop, or change the pattern or timing of fishing in an area.
- Change fishing practices to reduce risks of polluting, harming other species, or damaging the sea floor.
- Change behaviour to avoid catching non-target fish species, to reduce bycatch, and to reduce potential discards.
- Change behaviour once non-target species have been caught.
- Invest in activities such as stock enhancement or habitat creation to offset negative environmental effects.

The objective of this research, commissioned by the Ministry of Fisheries (MFish), was to develop a decision support system to assist the Ministry to select the best combination of 'instruments' for internalising the environmental externalities of commercial fishing. This paper provides an outline of the framework and process that have been followed to develop this system.

2. Fishery Management Instruments

Many fishery externality management instruments have been invoked and used around the globe, often in an attempt to reduce or prevent excessive harvesting of fish species, although some are used specifically to tackle fishing environmental externalities. A large literature exists exploring the effectiveness of various fisheries management policy tools and the requirements for their success (eg. Hanna 1997, OECD 1997) . Table 1 describes the attributes of different policy instruments for internalising environmental externalities and their applications to fisheries management.

Table 1. Management Instruments.

Instrument	Main world uses	Current NZ uses	Applicability to fishing
Regulatory			
No take zones	Protect juveniles, spawning areas etc		No fishing in specified zones means externalities not created
Marine Reserves	Protect juveniles, spawning areas, etc, protect habitat	Banks Peninsula, Long Bay etc	Area set aside for preservation of marine species
Closed seasons, areas	Protect juveniles, spawning areas etc	Near sub Antarctic islands.	No fishing during designated times and /or in prescribed areas.
Size or sex selectivity	Direct effort away from specified ages, sex individuals	Rock lobster, size requirement	Requirement for fishers to return to sea all prohibited catch
Bycatch Reduction Devices (BRD)	Reduce rate of bycatch of fish and other species	Pingers on gill nets	Vary technology used while fishing to reduce bycatch of fish or other species
Technology ban	Prevent externalities associated with specific harvesting technologies	Drift netting ban	Reduce bycatch by only allowing techniques which cause few externalities

Input limitations	Reduce externalities associated with number of potlifts, boat days etc		Reduce volume of fishing activity and associated externalities
Catch limitations	Reduce externalities associated with effort	Foveaux Strait oysters	Limit total harvesting and associated externalities
Retention and utilisation requirements	Reduce dumping of target and non -target species	Catching Against Anothers Quota (CAAQ), Fishing Against Anothers Quota (FAAQ)	Allow non target catch to be landed, not dumped
Financial systems			
Taxes	Provide incentive to reduce, eg, pollution	Conservation Services Levy, applied to some non-fish bycatch	Apply tax to variable inputs, boats, outputs, to reduce profits and externalities
Subsidies	Reduce costs of inputs	R&D assistance	Reduce costs of developing BRD
Environmental performance bonds	Provide financial incentive to avoid creating externalities	Mining, biodiversity protection	Provide incentive to not damage habitat or marine ecosystem
Financial inducements	Bribe to behave in desired way		Financial reward if do not create environmental externalities
Individual Quota, Tradable Quota, Vessel Quota (IQ, ITQ, IVQ), Share fisheries	Reduce race to fish	New Zealand Quota Management System	Creation of rights reduces need to race, provides incentive to maintain asset

Voluntary approaches			
Co management	Right holders draw up operating systems	Challenger Scallop Enhancement Company	Peer agreements reduce externalities
Codes of practice	Agreed behaviour which limits externalities	Hazardous Substances and New Organisms (HSNO) code, Agchem	Industry develop, adopt, codes which limit or preclude externalities
Accredited environmental management systems	Industry develops systems - externally audited pre-accreditation	Marine Stewardship Council, ISO 14001	Industry develop, adopt, systems with environmental policy which aims to limit or preclude externalities
Conservation easements	Negotiated agreements restricting behaviour	QEII Trust, Ducks Unlimited	Negotiated agreement to not take certain actions, eg, create externalities
Legal Remedies			
Tort law	Liability for pollution damages	Resource Management Act, a 'strict liability' law	Potential damages claims provide incentive to avoid creating externalities
Education and Information Supply			
Publications, guides, kits, etc	Numerous, e.g., information brochures, best-practice guides	Numerous, e.g., biodiversity protection	Informed people change behaviour, not create externalities
Informal regulation, e.g., environmental reporting	Toxics Release Inventory and corporate environmental reporting		Information release plus community pressure, modifies firm behaviour

3. Evaluation Criteria

Determination of which instruments are ‘best' requires criteria to judge performance and data to evaluate performance of the instruments. Slooten and Dawson (1995) note the limitations identified in most evaluative studies of the performance of fishery management instruments. Clear and robust criteria are necessary to evaluate performance as a basis for selecting appropriate management tools.

Five sets of criteria have been analysed to develop a set of specific outcomes against which policy instruments may be evaluated. The five criteria areas are environmental, Treaty of Waitangi, economics, socio-cultural, and management. Criteria within each of the sections vary in terms of the strength of direction they give. For example, the environmental and Treaty of Waitangi criteria are prescriptive because they are mandatory under existing legislation. Economic and social criteria are less prescriptive because policy advisers and decision-makers have greater latitude to consider these. Management criteria fall in between. A full discussion of how decision criteria were developed and justified is provided in Cullen, Hughey, Kerr and Memon (2000), the following sections briefly describe the nature of the decision criteria.

3.1 Environmental criteria

The development of environmental criteria requires consideration of:

- The Fisheries Act (1996) and other legislative requirements
- International treaty obligations
- Government ‘resource management/environmental' policy.

The Fisheries Act has been developed in an integrated way. It draws on international conventions eg. United Nations Convention on the Law of the Sea (UNCLOS), and is complementary to related legislation (ie. the Resource Management Act 1991) and policy, such as the Environment 2010 Strategy (Ministry for the Environment, 1995). Because of this approach to development of the legislation, it has been possible to integrate more recent environmental management considerations into development of fisheries policy and its implementation. Specifically, development of the Proposed Environmental Performance Indicators of the Marine Environment (Ministry for the Environment, 1998) builds on key Fisheries Act requirements.

3.2 Treaty of Waitangi criteria

The Treaty of Waitangi 1840 is the founding document of New Zealand as a nation. It is part of the law of New Zealand to the extent that it is incorporated into statute. A number of statutes relating to the marine environment incorporate reference to the principles of the Treaty and to the values and traditional relations of Maori with natural places and resources. Relevant statutes include the Fisheries Act 1996, the Conservation Act 1987 and the Resource Management Act 1991.

Through the Treaty, the Crown confirmed and guaranteed the existing rights of *tangata whenua* (original inhabitants) to land and resources, including rights in respect of intangible *taonga* (treasures). Maori tribes have guaranteed to them under Article II the right to retain (and have restored to them if taken without consent) tribal resources and *taonga*, and the right to manage them according to their cultural preferences. For this reason, it is imperative that the choice of policy instruments to address environmental externalities associated with commercial fisheries is assessed in terms of implications for Maori.

3.3 Economic criteria

There are five broad economic requirements for assessment of the performance of policy instruments to address environmental externalities:

1. Productive efficiency (including transaction costs)
2. Encouragement of innovation (dynamic efficiency)
3. Profitability/International competitiveness
4. Cost-effectiveness/Least cost policy
5. Internalisation (full-cost principle).

Cullen, Hughey, Kerr and Memon (2000) identify what is meant by each of these criteria, and how they may be assessed in practice. The key requirement is to minimise the economic cost of internalisation when imposing the “polluter pays” principle. Impacts of each policy on transaction costs, market power and windfalls and/or wipeouts should also be considered.

3.4 Socio-cultural criteria

There are three major areas for socio-cultural criteria development:

1. Community
2. Protection of access to recreational fishers
3. Equity

Community

Introduction of fisheries management policies can have significant effects on some communities that are heavily dependent on fishing for employment and income. For example, the New Zealand Government removed part-time fishers from the industry in 1983 by declaring all fishers who received less than $10,000 per annum or 80 percent of their income from fishing, to no longer be eligible to fish commercially. This action removed between 1500 and 1800 fishers from the industry while reducing the catch by less than 5% (Wallace, 1997; Memon and Cullen, 1996). The outcome for those removed was potentially very severe, as many of those removed from the industry lived in poor, isolated communities that did not offer alternative employment opportunities.

Recreational fishing

The rights of recreational fishers are different from those of commercial quota holders, and have not as yet been well defined. Compared to the commercial quota management system and the recently established regulations for Maori customary fishing, the recreational sector has no equivalent framework for precisely determining rights in the marine resource. For many New Zealanders, however, the freedom to go fishing is considered a birthright.

Equity

Equity questions arise not only on the consumption side of public policy (“who benefits?”), but also on the production side (“who pays?”). There is no clear right answer to what should be an appropriate distribution of such benefits and costs to society's members. There are several well-established normative positions from which equity may be judged. Consequentialist approaches evaluate outcomes (Sen, 1984). The maximin principle (Rawls, 1971) and utilitarianism both emanate from this perspective, but can yield quite different outcomes. Libertarians and procedural justice advocates argue that outcomes are irrelevant as long as the processes leading to them are fair (Nozick, 1974). Entitlement theories of justice propose that benefits should be distributed according to effort, contribution, potential, or other measure of merit (the “just desserts” principle) (Sen 1987). These different theories of justice often come into conflict. One approach at conciliation is the concept of superfairness, which incorporates both an equality principle and the libertarian principle; starting from equal allocations, but allowing trade to lead to mutually preferred, but unequal outcomes (Baumol, 1986).

3.5 Management criteria

Fisheries managers have limited resources available to achieve fishery management objectives. Managers are expected to prefer internalisation mechanisms that can be implemented at moderate cost and are effective, in all situations, particularly when conditions are less than optimal. Non-optimal management conditions are frequently encountered in fisheries because of remoteness, a hostile natural environment, bad weather, and limited information. These conditions mean that managers cannot be aware of all activities occurring in the fishery and fishers may have their responses to management initiatives constrained by environmental conditions. Fisheries managers frequently consider the following ‘managerial' criteria when evaluating internalisation mechanisms.

Introduction and modification

Some fisheries policies require new legislation. Others can be introduced and varied by a change of regulations – a much simpler process. Speedy improvement in situations where externalities are present will be favoured by instruments that can be easily introduced and varied.

Administration costs

Administration costs will be determined by the location of the fishery – inshore/mid-water/deepwater; by the ease or difficulty in achieving compliance with the system; and by the costs of monitoring fishing activities. Budgetary pressures will force fisheries managers to prefer low administration cost mechanisms. Some mechanisms have potential to be self-funding by requiring payment of fees by industry participants, increasing their likelihood of acceptance by fisheries managers.

Infrastructure requirements

Some internalisation instruments may require that fisheries managers have specific items of equipment. For example, deepwater capable ships may be necessary for monitoring and enforcement of some management instruments. Where these are not available to fisheries managers, alternative mechanisms must be selected to avoid the infrastructure requirement.

Information requirements

Section 10 of the Fisheries Act deals with the Information Principles. Regulatory authorities often have poor information and this can restrict their ability to successfully apply internalisation instruments. Where information availability is weak internalisation instruments that make least information demands are likely to be preferred.

Performance in sub-optimal conditions

A first best internalisation instrument in optimal conditions may perform poorly in sub- optimal conditions. Fisheries managers often operate in second best worlds of limited resources, poor information availability, multiple causes of externalities, etc. Fisheries management may be best served by versatile internalisation instruments that operate satisfactorily in many situations, rather than a mechanism that performs well only in ideal conditions.

Pressure on fisheries management staff

Some fisheries internalisation instruments require frontline staff to tackle risky tasks, or to deal with unpleasant situations. These pressures require specially trained fisheries management staff, payment of higher wage rates, and their overall effect is to increase costs of fisheries management. Internalisation instruments which do not lead to confrontation, do not require specially trained staff, or expose fisheries staff to risk, are likely to be more attractive to fisheries managers.

An iterative process was used to develop these areas of concern into a list of salient criteria. The process entailed ongoing discussions with the Ministry of Fisheries, industry, *tangata whenua*, NGO and recreational interests. The resulting list of criteria is reported in Table 2.

Table 2

4. Decision Support System

The wide range of potential instruments (22 have been identified in this study, although there are many more), the large number of evaluative criteria (19 identified here), and the differences in weights that people attach to different evaluative criteria ensure that decision making to address fisheries externalities is a highly complex strategic planning task (McLeod, 1993). In the language of Simon (1977, p.46) these are novel, non programmed decisions … 'which deserve a custom-tailored treatment'. Such ill-structured decision problems are situations in which decision support systems can be useful. These tasks are typically characterised by situations in which preferences and judgements are essential, and decision criteria are numerous, often conflicting, and are dependent on the perception of the user (Klein and Methlie, 1990). The decision support system 'GoFish' has been developed to simplify this process and to enhance the quality of debate around fishery management decisions (Kerr, Hughey and Cullen, 2000).

Decision Support Systems (DSS) have been developed in the past 30 years to enable managers to more effectively grapple with semistructured problems. DSS typically assemble information, identify alternative policies, contain modelling or simulation components, and evaluate the alternatives. Group Decision Support Systems (GDSS) allow a group to exchange ideas, opinions and preferences for alternative policies within a shared environment (McLeod, 1993). Decision support systems are expected to result in better quality decisions, improved efficiency, better communication amongst decision makers, and improved learning (Klein and Methlie, 1990).

GoFish is an additively linear decision model that follows in the traditions of Leopold, Clarke, Hanshaw and Balsley (1971). For each evaluative criterion GoFish multiplies user-derived numerical scores for expected outcomes and importance to obtain an item score for each evaluative criterion. Item scores are added across all evaluative criteria to obtain an overall score for each policy instrument. Instrument scores are compared to identify and report those with the highest scores. GoFish is deterministic and static (Klein and Methlie, 1990). It is located at the high end of the complexity scale, since it proposes decisions (Alter, 1976).

GoFish uses a hierarchical structure to simplify the decision making process. The initial step is choice of the type of fishery in which the externality occurs (Figure 2), which is necessary because the effects of management instruments vary across fishery types. The second step in the process is selection of critical criteria requirements (Figure 3). At this stage, the operator is required to identify any outcomes that must be achieved. (An example is Maori customary fishing rights and practices, which, by law, must be protected). GoFish then checks to verify that there are instruments capable of meeting this 'critical criteria' requirement. Should there be no instruments meeting all critical criteria, the operator is prompted to slacken the criteria until at least one viable instrument is identified. The third step in the process is application of a weighted matrix scoring

system to the subset of viable solutions. In the final step, one hundred points are allocated by the operator across all evaluative criteria, excluding those already deemed to be essential (Figure 4). GoFish scores each of the viable solutions and reports them and their scores in order (Figure 5).

Figure 2

Figure 3

Figure 4

Figure 5

A key step in implementation of GoFish is development of effectiveness ratings. Table 2 shows draft effectiveness ratings of 22 instruments against 19 criteria, a total of 418 ratings. These ratings can be changed in GoFish, reflecting the group decision support philosophy underpinning the process. There is no presumption that the ratings in Table 2 are “correct” or “final”, they are intended as a starting point for a discursive process which recognises the political nature of decisions about fisheries management (Keen and Scott Morton, 1978).

The ratings in Table 2 are scored on a range from –4 to 4. A score of zero indicates no effect, while a 4 signals complete success in achieving the particular criterion. Negative scores indicate that the instrument is counter-productive on that criterion.

GoFish has a wide range of potential applications. For example, it can be used:

- to let parties apply it independently in order to identify differences between parties in criteria weightings, and therefore to focus debate on key issues;
- to determine whether there are any instruments which will completely resolve a specific fishery problem, eg. mammal by catch in the trawl fishery;
- to determine whether there are any instruments which might be used extensively to deal with a potentially widespread problem, eg. pollution;
- to identify the best instruments to deal with issues, even if none of them completely resolve that problem, and to test sensitivity to criteria importance changes;
- to identify sets of viable solutions to allow more concentrated investigation of a small number of instruments, for example MFish may want to find the set of instruments that is 'least cost to them' for a fisheries problem;
- to defend (or play devils advocate) use of a particular instrument in specific circumstances; and/or
- to identify whether a small number of instruments could resolve several problems, resulting in simplified management.

Validation

Field testing on key participants in the fisheries policy process was used for initial validation of GoFish. This group included fishers, policy makers and environmental representatives. They were presented with the internalisation instruments and criteria for measuring effectiveness and minor changes were made to incorporate stakeholder perspectives. Subsequently the operational Decision Support System was demonstrated at the Ministry of Fisheries Socio-Economic Research Group meeting and attracted positive comment.

5. Discussion

Characteristics of the decision support system are that it:

- identifies internalisation instruments that definitely cannot meet key criteria;
- analyses the remainder to identify those that best meet the evaluative criteria; and
- produces a report that compares the most promising internalisation instruments.

GoFish is an extremely simple tool that is intended to help analysts to clarify issues and not to make decisions for managers. It is limited because of its design characteristics, information requirements, and inbuilt assumptions.

Design Characteristics

GoFish looks at using single instruments to address single problems. Clearly, the real world is much more complex than this. Most fisheries are characterised by a number of problems and experience has shown that solutions that rely upon several instruments often work better than application of a single instrument. What is more, fisheries are not discrete and management actions designed to address one fishery can have unintended outcomes in another. These conditions signal the need to identify a portfolio of management instruments that work in harmony. They also raise the issue about how far one should attempt to go in formulating a decision support system, as we note below.

GoFish is designed as a tool to clarify issues in fisheries management that are not currently being addressed. It is helpful because it expands the range of solutions that may be considered, and forces people to question their values and the impacts predicted from application of particular instruments. Extension of the system to handle multiple problems across several fisheries and to combine instruments would require a much more heroic set of assumptions than those already employed. There is a risk that further “black boxing” may result in less discussion rather than more. That appears to be an outcome that could seriously jeopardise fisheries. If the intent of the decision support system is to mobilise expert knowledge, then simple decision support systems, like GoFish, may be superior to more complex systems.

Information requirements

There is a lack of knowledge about many aspects of the environmental impacts of fishing. Further, there is little certainty about the relative severity of impacts within or between fisheries. Scientists and managers need to address these issues so that decision makers can be assured they are working on the issues of highest priority. In many circumstances the effectiveness of instruments is unknown, yet this information is necessary to operationalise GoFish. Scientists, fishers and fisheries managers need to be improving our knowledge base in these areas. There may be a need, given the above, for fisheries managers to learn-by-doing to understand the impacts of instrument implementation. Small scale, controlled applications of management instruments whose effects are unknown may yield extremely important information on instrument effectiveness.

Our evaluation of the effectiveness of instruments within different fishery types is likely to be different to evaluations undertaken within the Ministry of Fisheries or by other analysts. This might be interpreted initially as a limitation of the system. However, upon closer reflection it might better be considered a strength. This conclusion is reached because differences can help expose important tensions between different actors in the fishery management arena. For example, environmental groups may operationalise GoFish with dramatically different importance scores and/or critical criteria to those used by commercial fishers. There could be agreement on instrument effectiveness, or the groups may have different views on instrument impacts. Independent operation of GoFish can identify these tensions by comparing the inputs used by different operators, allowing subsequent discussions to focus on salient points of difference. This process can identify the areas where information is most in need of improvement.

Assumptions

GoFish employs a linearly additive objective function. Each outcome score is multiplied by its weight and all such products are summed to derive the overall score for the instrument. The system could potentially be improved by utilisation of a non-linear objective function to allow for diminishing marginal benefits. Appropriate forms could include polynomial specifications, multiplicative models or models including interactive effects.

Another avenue that can go some way to achieving the same ends is to adopt a non-linear scoring system for each cell in Table 2. The completely subjective scores in Table 2 may explain some of the differences between different analysts' scoring of instruments against criteria. Consequently, one area for improvement is to standardise the scoring process by careful specification of thresholds for each score category so that different evaluators who hold the same beliefs apply similar scores. However, if a decision support system is to be used to encourage debate about critical issues, it may be advantageous for parties with differing views to undertake the scoring together. In these circumstances the final scores derived may have less relevance than the process undertaken to obtain them.

6. Conclusions

Development of a credible decision support system presents a difficult challenge. One of the primary benefits from the development of GoFish has been increased understanding of the complexity of fisheries management, the poor quality of fisheries information, the lack of clarity in objectives for management, and the poor understanding of the impacts of management instruments. Until these issues have been addressed decision support systems will be able to do little more than focus debate on key issues and identify management instruments that are worthy of closer scrutiny. They are certainly not in a position to replace analysts with a clear understanding of the issues involved in fisheries management. While their role is limited, the benefits of issue clarification are likely to be sufficient to justify further development of tools like GoFish.

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