

Database documentation and critical review of national habitat compensation literature

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1.0 INTRODUCTION

The Department of Fisheries and Oceans' (DFO) *Policy for the Management of Fish Habitat* (hereafter referred to as the Policy) (DFO 1986) gives guidance to developing an operational policy specifically for habitat compensation. However, it is strategic in nature and provides little specific direction on compensation. Decisions on compensation policy approaches are presently left to the discretion of individual habitat officers and their managers. This often leads to inconsistent application and can erode public confidence in the Policy. It has been suggested that success of compensation is not always certain (DFO 1998). The National Habitat Compensation Initiative (NHCI) was undertaken to review specific policies, procedural, legal, and technical/scientific components of habitat compensation issues. The goal of NHCI is to develop a clear and sound policy directive and a best management practices manual on habitat compensation providing direction on the Policy (DFO 2000). These products will support and enable staff to make more informed, high quality, and consistent decisions.

Under the Policy, development projects or activities that will cause a harmful alteration, disruption or destruction of fish habitat (HADD) are first assessed in order to avoid adverse impacts. This may involve not authorizing the project, moving to another site, or using mitigative activities to minimize or eliminate the intensity of the impact. If, after this, a project is considered for authorization by DFO where it has been proven impossible or impractical to maintain the same level of habitat productivity, compensation is initiated. Habitat compensation is required to achieve the goal of no net loss (NNL) of the habitats that support the productivity of Canada's fisheries resources, as stated in the Policy (DFO 1986).

Any instruction, action, intervention, construction or undertaking to offset an unmitigated impact to fish habitat is considered an effort towards compensation (DFO 1998). Where there is a sufficiently detailed fishery management plan or where information on limiting factors exists a situational hierarchy is utilized to determine the type of compensation to employ. In most cases a universal compensation hierarchy of preferences, as stated in the Policy, for compensation options exists with levels ranging from like habitat compensation to artificial production (DFO 1986). In the habitat compensation directive (DFO 2000), this hierarchy was explained in greater detail. In order of preference, the levels in the hierarchy are: 1) create like-for-like habitat in the same ecological unit to benefit affected populations; 2) increase like-for-like habitat productivity in the same ecological unit to benefit affected populations; 3) create unlike

habitat in the same ecological unit to benefit affected populations; 4) increase unlike habitat productivity in the same ecological unit to benefit affected populations; 5) create or increase habitat in a different ecological unit to increase the productivity of a different population of the same species; 6) create or increase habitat in a different ecological unit to increase the productivity of a different species; and 7) undertake rare measures as a last resort, such as deferred compensation or restoration of contaminated areas or artificial production. The latter option is to be considered only in those rare cases when it is impossible to compensate for the habitat itself, either in the same or different ecological unit. Artificial production can only take place if the activity is in accordance with objectives established in the local fisheries management plans, that genetic and other biological factors are satisfied, and practical and proven techniques are available (DFO 2000).

There are three important notes concerning compensation activities. First, compensation is not an option when dealing with chemical pollution or contaminated effluent. Mitigation of such problems must occur from the outset by installing and operating reliable control techniques. Second, financial compensation for tangible economic losses is prohibited. Compensation deals only with those activities that are designed to maintain the productive capacity of fish habitat. Thirdly, no compensation options will be explored for habitats where the productive capacity is very high. No loss of these habitats will be permitted (DFO 1998).

Phase I (1999-2000) of the NHCI contained an information gathering phase internal to DFO. As one step towards this, a bibliographic database was developed to assist in reviewing scientific/technical components of habitat compensation issues.

The purpose of this report is to document the database and use the information to identify strengths and weaknesses within the habitat compensation and related literature. National habitat compensation documents were compiled, classified, and critically reviewed. In this report, the database was used to analyze patterns related in the national compensation literature. We examined if there were any patterns of regionally recommended documents, document categories, compensation hierarchy and what level of proven scientific basis existed behind the compensation techniques used.

2.0 METHODOLOGY

Literature related to habitat compensation for both freshwater and marine systems was first compiled and then organized for input into the bibliographic database. The database was developed in MS Access using several unique fields to classify and review the literature. Not all fields were used for each document record, as some documents did not contain information we were interested in. These fields were left blank indicating this information was not available. The database was then used to classify and critically review the patterns found within the habitat compensation literature.

2.1 Compilation and Input of Literature

Priority for compiling the habitat compensation literature was first directed to those documents recommended by regional fish habitat management staff. Second priority was given to documents obtained through a search of the fisheries literature. This was conducted using several searching methods including the Internet to access governmental and non-governmental databases and on-line publications. Aquatic Sciences and Fisheries Abstracts (ASFA) and governmental and academic library systems were also searched. All documents at any level of publication status were considered, however, priority was first given to Canadian literature, followed by U.S. literature and then all other sources. The compiled literature was reviewed for several types of information (see Section 2.2) which was recorded in the database. Every effort was made to standardize the input of the literature into the database. This was done by including as many set potential input values in the database as possible. Also, by having one person (B. Cudmore-Vokey) input the literature, an attempt was made to decrease the amount of input error caused by bias in the interpretation of fields.

2.2 Definitions of Database Fields and Literature Classifications

The annotated bibliographic database was organized into five main categories: citation, habitat, compensation, monitoring, and abstract. These categories were further broken down (Figure 1) and the fields are defined below:

2.2.1 Citation

In addition to general literature citation fields (title, author, date etc...), three unique fields were developed to classify the habitat compensation literature and provide more information beyond the typical citation information. These fields are defined below:

- **Document type** – each document was categorized as one of the following document types: book, chapter in a book, electronic copy (such as a web site), fact sheet/pamphlet, guidelines/policy, journal article, manual, proceedings (such as from a workshop or conference), report (such as a private consultant report), or technical report.
- **Document identification number** – every document inputted into the database was assigned a number for ease in locating specific documents at a later date. Most documents will be catalogued in the Canadian Centre for Inland Waters' Fish Habitat Management library in Burlington, Ontario and the document identification number will correspond with the call numbers assigned.
- **Classification ID** – each document was classified into one or more of seven categories which are describe below with examples:
 - ◆ *HADD and compensation determination procedures* – documents which detail how to determine what is lost or damaged and how much compensation is required. Examples are: impact assessment and prediction, risk analysis, and quantification schemes (Defensible Methods, Instream Flow Incremental Methodology).
 - ◆ *Habitat compensation techniques* – documents describing actual techniques and interventions for restoring or improving fish habitat to compensate for other loss or damage. Examples are: techniques or methodology used in habitat creation, rehabilitation, restoration, enhancement, and improvement.
 - ◆ *Habitat mitigation techniques* – documents describing actions that can be taken to minimize or avoid impacts as development takes place. Examples are: mitigation procedures, and conservation and protection guidelines.
 - ◆ *Ecological fisheries principles for fish habitat management* – documents detailing how fish productivity metrics are linked to habitat metrics and how ecosystems are structured and function. Examples are: habitat suitability models, habitat classifications, and productivity models based on habitat features.
 - ◆ *Assessment procedures* – documents that describe those activities designed to assess the current situation or the results of an intervention. Examples are: habitat monitoring, inventory surveys, and experimental design.

- ◆ *Procedures necessary for establishment of integrated fish habitat management plans* - Examples are: watershed planning guidelines and ecosystem management frameworks.
- ◆ *Case study* – documents that describe specific case studies.
- **Source** – the source of the document was identified to include those documents suggested by DFO fish habitat management staff, those from the Internet (including ‘url’ address) and documents found in compiled literature reviews (with complete citation).

2.2.2 Habitat

The fields in this category were used to identify the location of the compensation activity, the habitat and the fish species associated with the activity.

- **Geographic location** – includes the country, province/state, and/or region of the activity described in the document.
- **Ecosystem type** – the type of ecosystem discussed in the document was first classified into freshwater or marine, then into the following defined categories from the NHCI working group dealing with case study analysis:
 - ◆ *Freshwater:*
 - large lake - larger than 1000 ha
 - small lake - smaller than 1000 ha
 - river - maximum depth more than 1 m
 - stream - maximum depth less than 1 m
 - wetland - lands that are seasonally or permanently covered by shallow water, as well as lands where the water table is close to or at the surface.
 - freshwater-all - covers all freshwater habitat types above.
 - ◆ *Marine:*
 - estuary - mouth of a river influenced by tide and marine saltwater
 - intertidal - area between the high tide and the low tide
 - nearshore - part of the subtidal influenced by coastal activities
 - offshore - part of the subtidal not influenced by coastal activities

- coastal salt marshes - wetland with vegetation adapted to high variation of salinity and temperature
- marine-all - covers all marine habitat types above
- **Habitat use** – the use of the habitat by fishes was categorized into spawning, nursery, foraging, rearing, and migration. Also included here was whether juvenile or adult fishes used the habitat.
- **Habitat temperature** – the thermal habitat was defined as one of the three following categories:
 - ◆ *Cold* - average daily maximum summer water temperatures are approximately 14°C.
 - ◆ *Cool* - average daily maximum summer water temperatures are approximately 18°C.
 - ◆ *Warm* - average maximum daily summer water temperatures are approximately 23°C.
- **Habitat substrate** – the substrate of the habitat described in the document was organized into one or more of the following categories: boulder, cobble, rubble, gravel, sand, silt/clay (mud), hard-pan clay, detritus.
- **Fish species covered** – lists the specific fish species or groups of fishes if stated in the document

2.2.3 Compensation

Described in this category are the activities detailed in the document pertaining to development and compensation. Compensation activities are further classified and evaluated.

- **Development activity** – the development activity referred to in the document is categorized using national and regional work codes from DFO’s Habitat Referral Tracking System (HRTS). Examples of some development activities are power development project, silvicultural activity, and dock construction.
- **Compensation activity** – the compensation activity described in the document is listed here and is defined as any instruction, action, intervention, construction or undertaking to offset an unmitigated impact to fish habitat (DFO 1998). Habitat restoration via artificial reef construction, species or stock rehabilitation via artificial production, and creation of spawning grounds are some examples of compensation activities.
- **Compensation hierarchy** – the compensation activity was classified into one of seven levels in the universal compensation hierarchy (fully described in Section 1.0):
 - ◆ *Create like-for-like habitat; same ecological unit; benefit affected populations*

- ◆ *Increase like-for-like habitat productivity; same ecological unit; benefit affected populations*
 - ◆ *Create unlike habitat; same ecological unit; benefit affected populations*
 - ◆ *Increase unlike habitat productivity; same ecological unit; benefit affected populations*
 - ◆ *Create or increase habitat; different ecological unit; same species*
 - ◆ *Create or increase habitat; different ecological unit; different species*
 - ◆ *rare measures as a last resort, such as artificial production, deferred compensation and restoration of contaminated areas.*
- **Evaluation ID** – the compensation activity is marked as a success, failure, or as unknown if the evaluation is not indicated in the document or if the activity is still in progress.
 - **Citation of Techniques** – includes any citation or source provided as scientific background or verification of the compensation techniques described in the document. If a source for further information is provided regarding a compensation activity or technique this is provided here.
 - **Limitations** – this field consists of any limitations of the compensation activity noted in the document, such as those related to location, ecosystem type, habitat or species.
 - **Success criteria** – any remarks in the document on what constitutes a success with respect to compensation are incorporated here and can include criteria such as changes in biodiversity, abundance, productivity or sport catch.

2.2.4 Monitoring

Any discussion in the document related to monitoring programs is categorized here with respect to criteria and duration.

- **Monitoring program suggested?** – if a monitoring program was suggested or recommended, this box is checked.
- **Monitoring criteria** – includes any suggestions for monitoring criteria and may include variables such as water flow, species inventory or water clarity.
- **Duration of Monitoring** – if a monitoring duration time was suggested, the time in months is included in this field.

2.2.5 Abstract

- **Abstract** – this field contains the abstract of the document, if available electronically. For those documents without an abstract, no abstract will be written for them.

It is important to note that for each individual document record, not all fields will be filled.

2.3 Critical Review of Literature

The database was used to analyze patterns found within the habitat compensation literature. It is important to note a limitation of the database review with respect to categorizing activities into the compensation hierarchy. As this database was not a compilation of case studies, many techniques described in some of the documents were not directly related to specific compensation projects for a specified loss of habitat. Therefore, assigning a hierarchy level was difficult. However, the best attempt possible was made and the resulting review was summarized with respect to regional differences, document categories, compensation hierarchy, and scientific basis.

3.0 RESULTS AND DISCUSSION

A total of 177 documents were compiled and entered into the database. The records were reviewed and the results grouped according to several categories of interest. These categories were: regional representation, document categories, compensation hierarchy, and source of scientific basis. An overall review of the compensation-related literature was also completed.

3.1 Analysis of Regional Representation in Database

This analysis dealt with where the document originated from with respect to its recommendation for inclusion into the database. It does not refer to the location where the activity described in the document took place. For example, although the Maritime region may recommend a compensation document outlining activities that occurred in the Pacific region, the regional representation assigned to that document was the Maritimes. As this was not a specific case study database and most documents in the database were generic explanations that often did not specifically originate from a particular location, analysis of regional representation of actual compensation activities was impossible.

From those documents that were specifically recommended by a DFO region, we were able to determine the percent representation within the database. The regions with the highest representation in the database were Maritimes (27%) and Central and Arctic (Ontario) (26%). Newfoundland (17%), Pacific (10%) and

Laurentian (9%) were the next highest. This was followed by Central and Arctic (Winnipeg and Nunavut) at 6 and 5% respectively (Figure 2).

Although each region recommended many more documents, those that were very localized and grey material were more difficult to locate in the timeframe provided. Access to those region-specific documents recommended by Central and Arctic (Ontario) was greater than for those from other regions. The Maritimes region, however, sent copies of several documents that were able to be easily included into the database. Also, high level of representation from Central and Arctic (Ontario), Maritimes and Newfoundland may be the result of a greater number of recommendations from national scientific journals and technical reports compared to the other regions. Access to these national documents was readily available.

3.2 Analysis of Document Categories

Each document could be classified into more than one category (see section 2.2.1). Therefore, the data were analyzed with respect to frequency of each category not solely the number of documents in each category.

Documents containing HADD and compensation determination procedures and mitigation techniques represent the highest frequency within the database. These were followed by ecological fisheries principles and compensation techniques. Much farther behind were documents on case studies, procedures for integrated FHM plans, and assessment procedures (Figure 3).

Those documents describing HADD and compensation determination procedures mainly involved studies on impacts of development activities rather than compensation determination. The many national and regional guidelines on protecting fish habitat during various development activities led to the high frequency of documents in the mitigation techniques category. Mostly habitat classifications and suitability indices made up the documents in the ecological fisheries category. The high degree of overlap of the document categories within the database indicates the generic nature of the documents.

3.3 Analysis of the Compensation Hierarchy within the Database

Each compensation activity described in each document was assigned a level within the compensation hierarchy. It is important to keep in mind the limitation to this activity which was outlined in Section 2.3.

It is apparent that most of the compensation activities in the database dealt with increasing habitat productivity, first unlike, then like-for-like habitat. Creating habitat, first unlike then like-for-like, was behind increasing productivity in frequency. Also the majority of compensation activities were within the same ecological unit and focused on the same species affected by the development. Very few compensation activities included artificial production as an approach to compensation and none of the activities described in the database focused on a different species and different ecological unit from the area of the development activity (Figure 4).

It is difficult to determine the reason for the differences of frequency between the hierarchy levels. Perhaps methods for increasing productivity are less expensive to conduct than constructing entirely new habitat. The view may be that constructing new habitats are not only more expensive but are more intensive, intrusive, and have a greater lag time and less certainty for achieving desired results. The preference for more compensation activities occurring in the same ecological unit and species is keeping with the priority of preferences in the hierarchy. For most development projects, it may make more sense to stay within the same unit and species with respect to ease in conducting the compensation activity and monitoring progress. Also in keeping with the order of preference in the hierarchy, there are few artificial production projects used as compensation activities.

A habitat compensation case study database was also developed as one of the interim products of Phase I of the NHCI (Lange *et al.* 2000). That database contained 122 case studies from across Canada. Several aspects of the case studies were inputted such as, HADD area, success of compensation plan and description of the development activity. These aspects were used to analyze regional patterns with respect to compensation. It is interesting to note the differences in the frequency of the levels of the compensation hierarchy found within the bibliographic database and those within the case study database (Figure 5). For all regional case studies, increasing unlike habitat productivity in the same ecological unit to benefit affected populations was one of the least chosen hierarchical levels (#4). Whereas, for the bibliographic database, this level represented the highest frequency within the hierarchy. There is a discrepancy between the frequency of what is recommended in the literature and what is actually being done in compensation plans.

3.4 Analysis of the Source of Scientific Basis Behind Compensation Activities

Of the 88 compensation activities in the database, only 29.6% provided some sort of source as a scientific basis for the activity. Among those sources, published material and general information were equally represented (46%). References to published material, such as journal articles and grey literature, were used as background to other projects using similar techniques or evidence of fish usage of a particular modification (artificial reefs, spawning channels etc...). General information included sources such as descriptions of life history traits, use of detailed diagrams or charts with indices such as flow rates, substrate, and construction material. Only 8% referred to offices (such as a natural resource agency) as a source of further scientific information (Figure 6).

Although almost half of those compensation activities referred to some type of published material, we don't know the scientific validity of these documents. Nor was there much legitimate basis of science provided in the general information group. Much of the information was diagrams to help the reader use the techniques described, not outlining scientific evidence for choosing the technique, how it works, and its success rate.

3.5 Overall Review of the Compensation-Related Literature

Some general observations can be made from the literature analysis. There were regional variations of the types of documents recommended (including those that were not inputted into the database). Newfoundland and Maritimes recommended more scientific literature, including technical reports, manuals and published journal articles. The Laurentian and Central and Arctic regions recommended a mixture of documents, but with more emphasis on guidelines/policies. The Pacific region had a heavier emphasis on consultants' reports than the other regions. Reports from the regions may be a reflection of the different ways DFO conducts its business with respect to compensation. For instance, some regions are more directly involved in developing compensation plans, which could account for the greater number of scientific documents recommended from those regions. Whereas, in other regions, such as Pacific, consultants have much experience with habitat compensation and are familiar with the literature and so those regions have not listed as much literature as it otherwise might have. These differences could lead to variations in decision-making with respect to compensation issues, variations in the hierarchy chosen and levels of science behind compensation activities between the regions.

The nationally available compensation-related literature is too generic to be of specific use to habitat management in their compensation decision-making. Most documents are species profiles rather than specific compensation issues. Other documents contain information on general habitat creation or rehabilitation rather than provide specific scientifically defensible methodologies. Often, these documents contain no guidance on amount of compensation needed (scientifically determined ratios) or long term successes. One exception was sent to us after completion of the database. This summary report outlined some of the research projects in the St. Lawrence pertaining to a variety of compensation techniques (Maurice Lamontagne Institute 1999). Availability of documents outlining pertinent quantitative methodology is lacking.

Much of the literature is very “grey”; mainly consultants’ reports which are not readily available to other regions, or even to other offices in the same region. The information contained is not subjected to peer-review and therefore may not be scientifically defensible. There was very little overlap in the documents recommended by the regions, providing support that there is very little standardization with respect to compensation issues and that most of the documents were very localized in nature. This limits the level of communication between regions. Next to consultants’ reports, much of the documents in the database are guidelines/policies which contain little to no science and quantitative methodology (Figure 7).

Overall, the amount of relevant information within the documents is greatly lacking. When the database was first developed, it was assumed that for most of the fields outlined, information would be available. It soon became clear that this was not the case. More often than not, many fields for each record remained empty due to lack of information (Table 1). This deficiency was most notable with regard to monitoring. Of the 177 documents in the database, only 30 (17%) contained some information on monitoring, mostly just a suggestion of monitoring with little information on developing criteria (6.2%) or duration periods (3.4%). This, coupled with the low number of assessment documents in the database (Figure 3), suggest that monitoring is not given a high priority or seen as important enough to include adequate information about it in the documents. With such little information on monitoring, there was, inevitably, little information available in the documents on the effectiveness of various compensation techniques.

The documents habitat management staff are relying on to help them with compensation issues are not scientifically defensible and are for the most part not helpful. There are no clear policy documents providing project-level guidance on making habitat compensation decisions. This deficiency needs to be corrected.

4.0 RECOMMENDATIONS

To achieve more informed, high quality, and consistent decisions with respect to compensation issues, the state of the compensation literature needs to be addressed. It is first important to make the database nationally accessible in order to encourage consistency in decision-making. The database will, at first, provide a valuable source to locate general habitat compensation material in order to assist fish habitat management staff. In the future, it will also provide background material on more specific compensation activities and the level of success of these activities. The lack of relevant and scientifically defensible literature suggests that more experimental and case study analysis research needs to be conducted in this area, thereby adding to the available literature for habitat management. Subjecting reports from both experimental research of potential compensation activities and further analysis of current case studies to peer-review would increase the level of confidence and defensibility within the national habitat compensation literature. It is imperative that there be a commitment to maintain the database at regular intervals and make it available on a national basis. This would help to increase communication and the flow of information and provide as up to date information as possible.

Learning the effectiveness of compensation activities should be given a higher priority, which is imperative to avoid repeating mistakes by documenting and communicating results of projects. This has been noted in the past with regard to rehabilitation projects (Hartig *et al.* 1996, Smokoroski *et al.* 1997). Development of a standard methodology for monitoring compensation programs, including criteria, duration and success, would increase the effectiveness and efficacy of these programs. It would encourage consistency and enable habitat managers to learn from past decisions, which will improve decision-making in the future. This process would use science to develop a flexible model with decision-tree characteristics to allow flexibility through adaptive management, turning science to practical and operational uses for habitat management.

Combining these two elements, research and monitoring, would address many questions, aiding management, in both the long and short term. Following a generic integrated framework of monitoring, research and management would compliment the different time scale needs of both management and science to the benefit of fisheries habitat (Figure 8). Inventory and monitoring elements of a monitoring program would lead to better assessment of projects, providing descriptive knowledge feedback to adjust monitoring programs for immediate benefits. The assessment results are based on a time and space scales which would provide valuable feedback on a short term basis, relevant to management decisions. Research designing experimental protocols to answers longer term questions with regard to compensation issues and desk analysis, using historical, existing data to test hypothesis are combined to assist with planning elements. Interaction between monitoring and research results is imperative to help both sides develop and test ideas. Results are then used to develop regulations that are then implemented for use in habitat compensation. This framework is intended to provide a generic template, not necessarily for use with specific authorized projects as some aspects of the framework would have to be adjusted according to the projects specific needs.

Consistency in the use of the hierarchy should be encouraged. This would include consistent terminology and a flexible method for determining the best level within the hierarchy for a specific project. These are further addressed in the *Habitat Compensation Directive* (DFO 2000).

Implementing these recommendations would strengthen the scientific basis for habitat compensation actions and help fulfill DFO's commitment to managing Canada's fish habitat. Utilizing scientific knowledge to identify the approaches needed for compensation or to justify actions already taken, will increase confidence in compensation procedures. Further scientific research into these issues is needed to allow staff to make more informed, high quality, and consistent decisions with respect to habitat compensation.

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Figure 2: Percentage of regional recommendations within the database

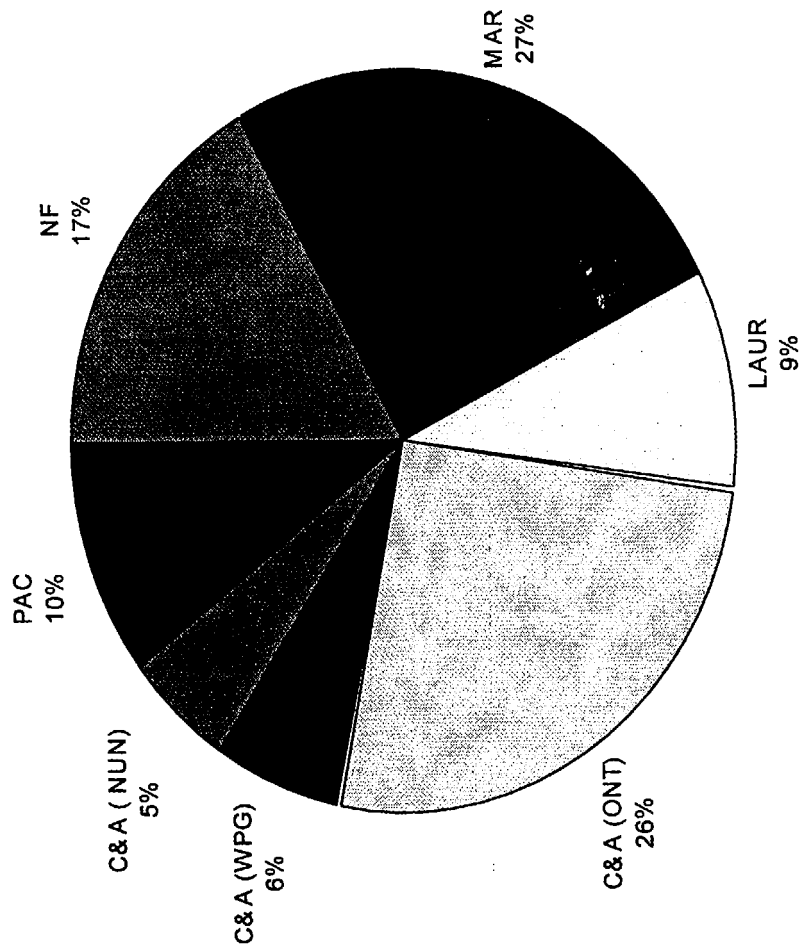


Figure 3: Frequency of document categories within the database

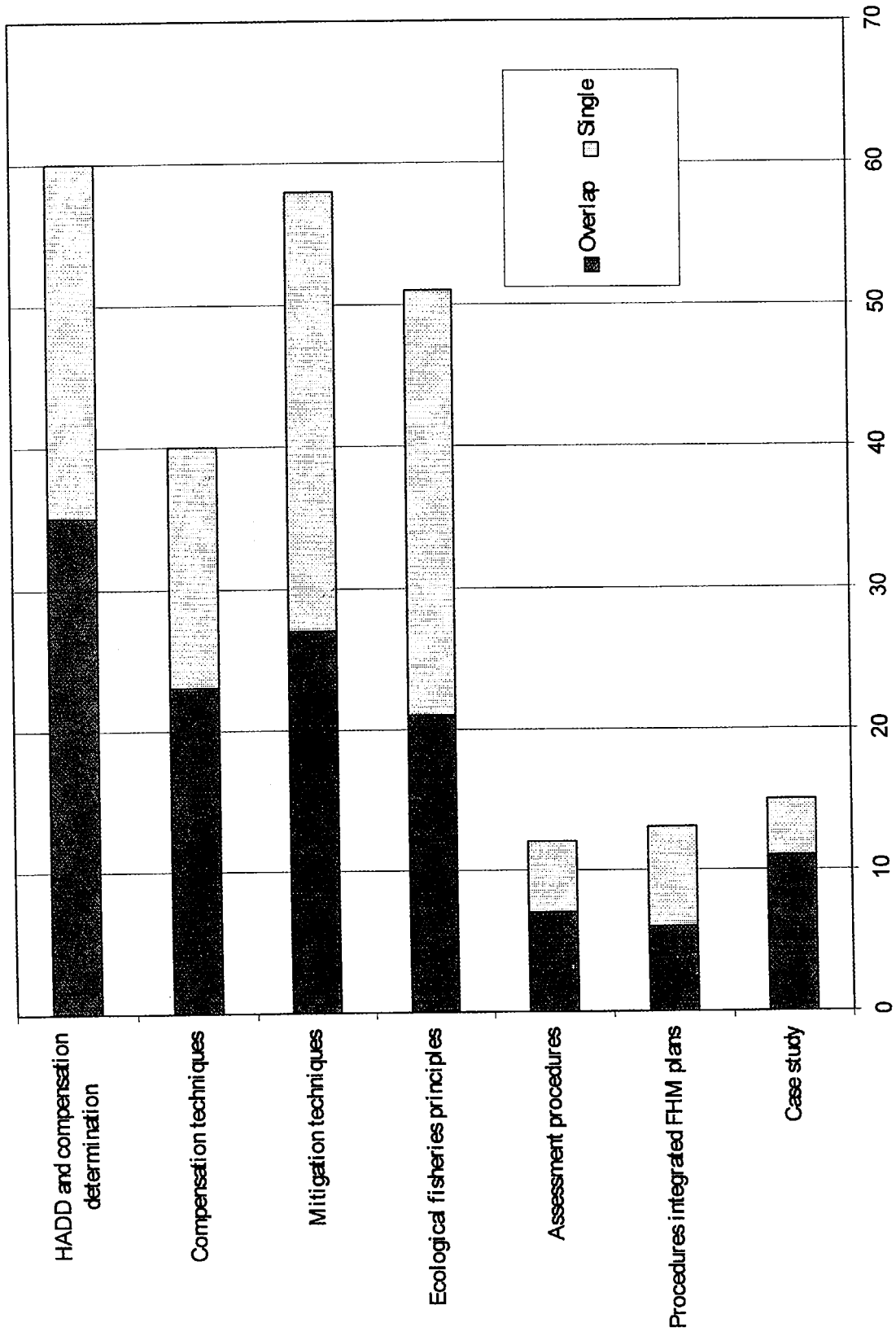


Figure 4: Frequency of compensation hierarchy levels within the database

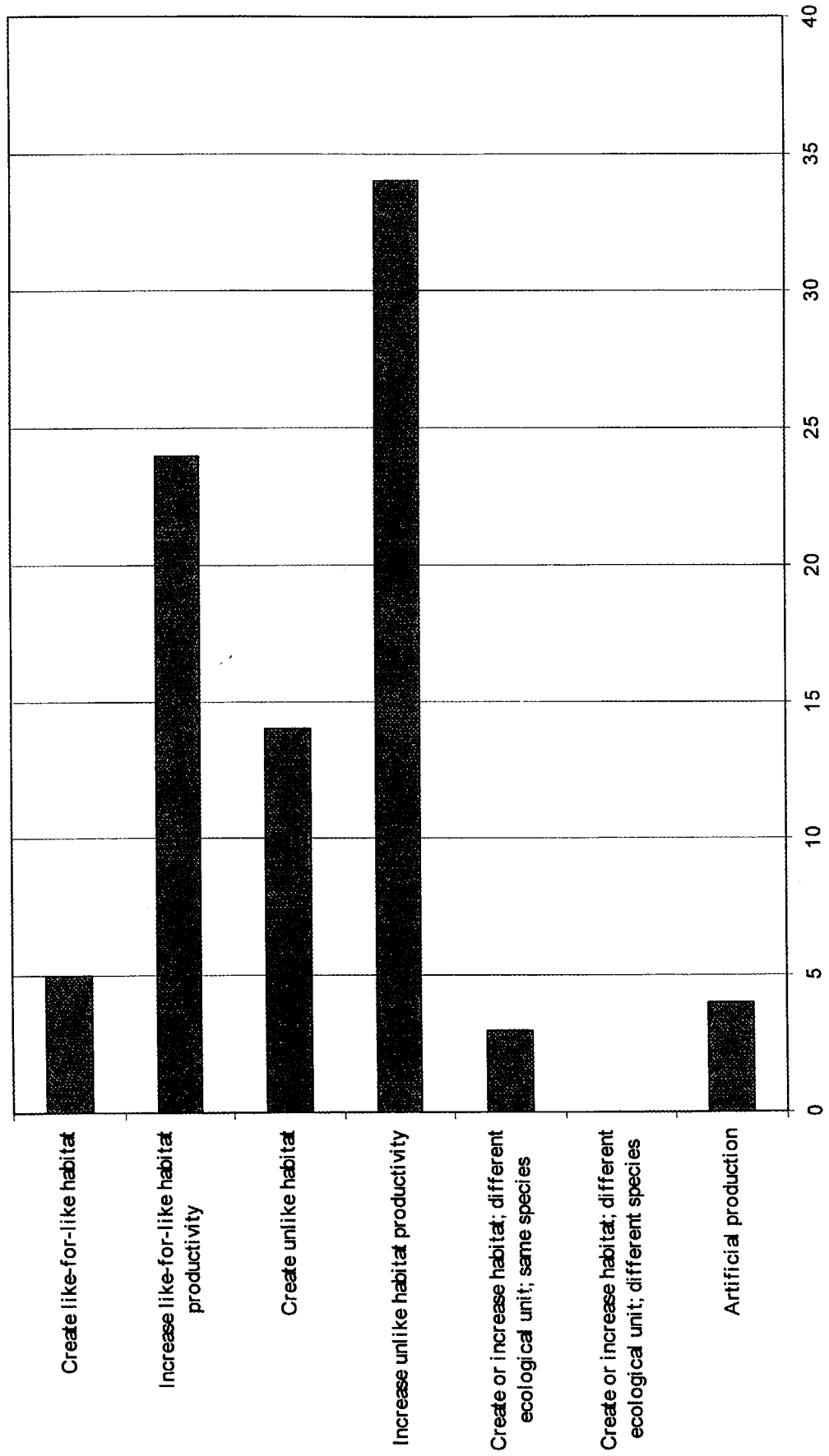
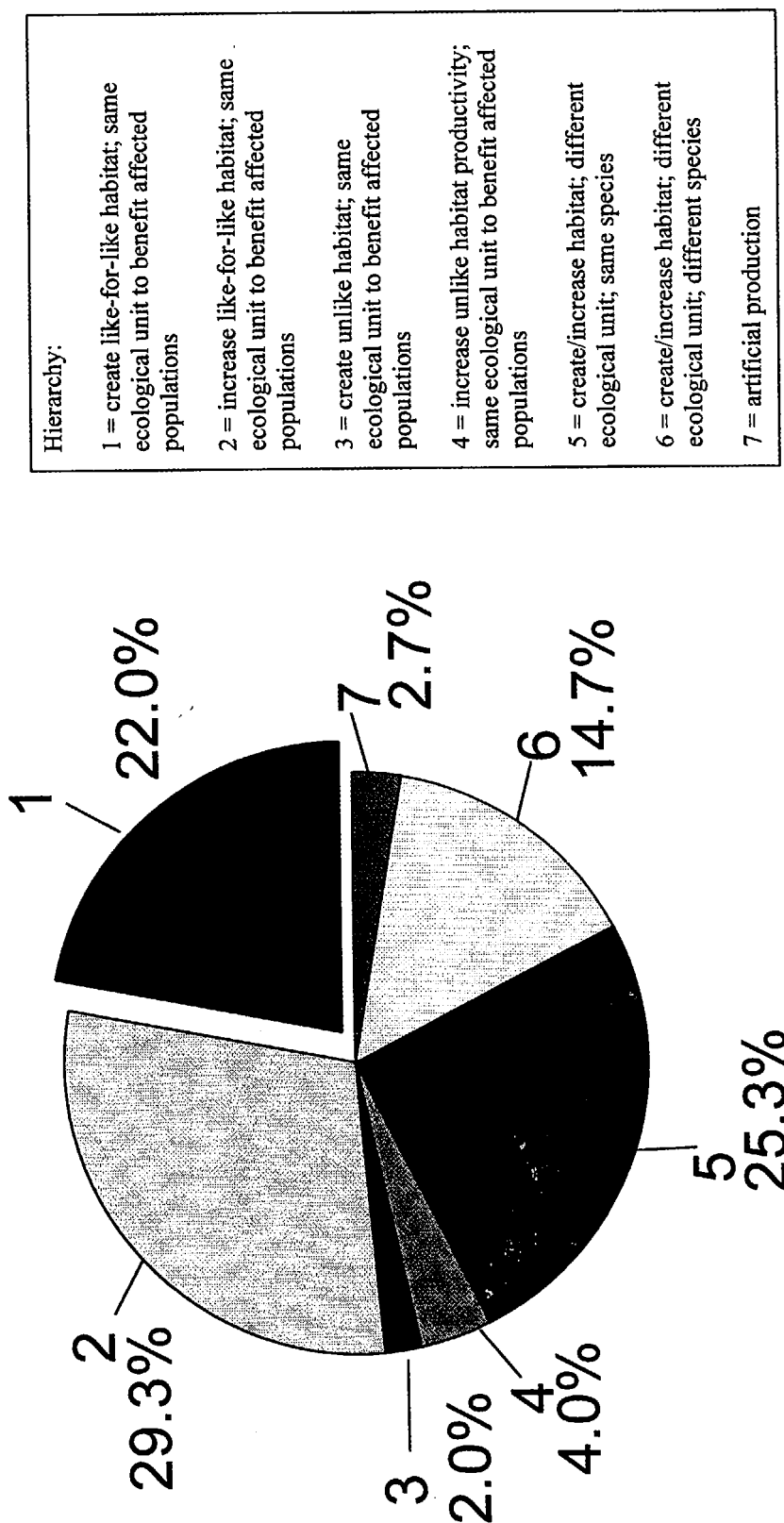


Figure 5: Frequency of compensation hierarchy levels within the case study database (From: Lange *et al.* 2000). (n=122 case studies reporting 150 hierarchy levels)



Hierarchy:

- 1 = create like-for-like habitat; same ecological unit to benefit affected populations
- 2 = increase like-for-like habitat; same ecological unit to benefit affected populations
- 3 = create unlike habitat; same ecological unit to benefit affected populations
- 4 = increase unlike habitat productivity; same ecological unit to benefit affected populations
- 5 = create/increase habitat; different ecological unit; same species
- 6 = create/increase habitat; different ecological unit; different species
- 7 = artificial production

Figure 6: Source of scientific basis within the database (n=26)

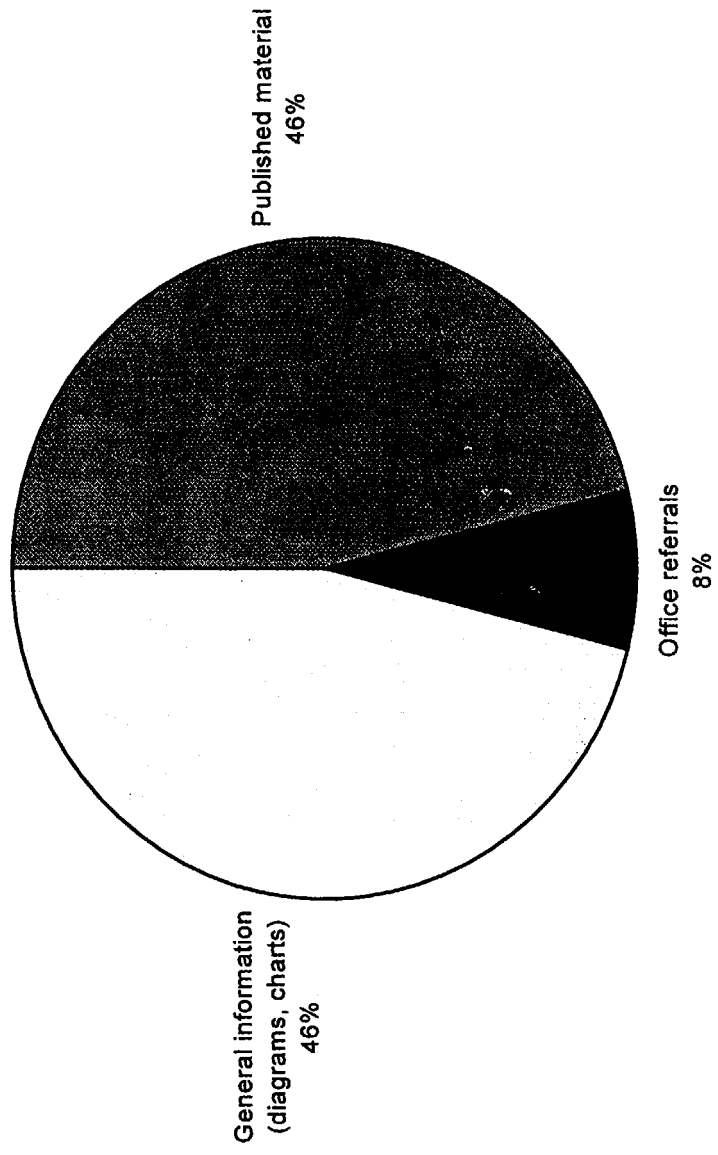


Figure 7: Document types within the database (n=177)

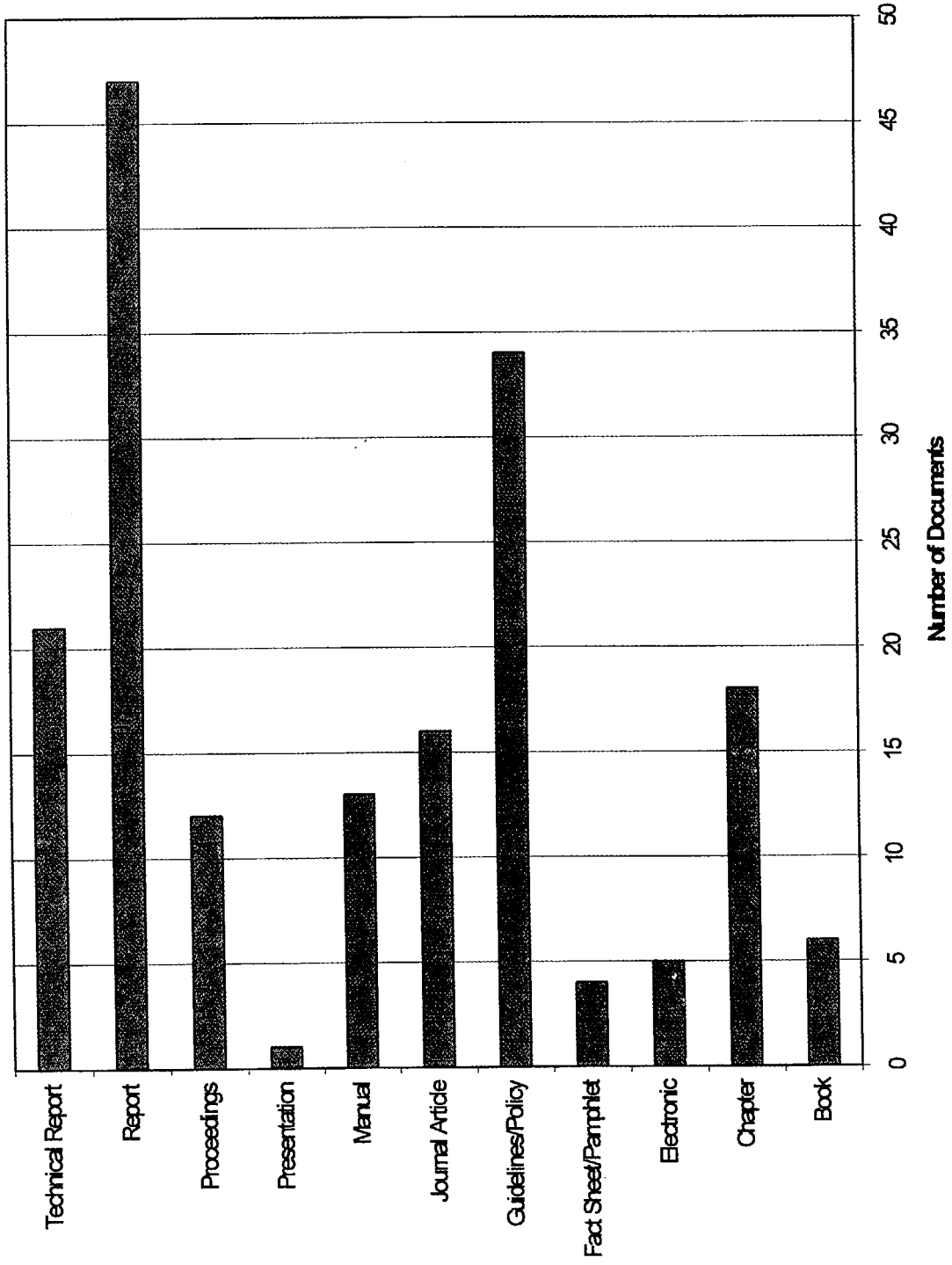


Table 1: Frequency summary of the three main database categories directly related to describing compensation plans (habitat, compensation and monitoring). (N=177)

DATABASE CATEGORIES & FIELDS	FREQUENCY
Habitat: (n=147)	
Geographic Location	130
Ecosystem Type	127
Habitat Use	35
Habitat Temperature	8
Habitat Substrate	9
Species	73
Compensation: (n=89)	
Development Activity	66
Compensation Activity	40
Compensation Hierarchy	38
Evaluation Identification	14
Citation of Techniques	12
Limitations	18
Success Criteria	15
Monitoring: (n=30)	
Monitoring Program Suggested?	30
Monitoring Criteria	11
Duration of Monitoring	6

Figure 8: Simplified generic model incorporating elements of research, monitoring and management into a functional whole. (Adapted from: O'Connor and Flemer 1987).

