Frame blending in specialized language

Harmful algal bloom

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According to Frame-Based Terminology (Faber et al. 2005, 2006, 2007), a crucial issue in terminology management is how specialized concepts should be represented within the knowledge structure of a scientific domain. This paper proposes a model of specialized concept representation based on conceptual frames (Faber et al. 2006, 2007; Faber 2011) and blends (Fauconnier 1999; Fauconnier and Turner 1998, 2002). Although frame-blending has been documented in general language (cf. Coulson 2005), it has not as yet been studied in specialized language. In this paper, we show how it can be applied to *harmful algal bloom* in the field of marine biology.

**Keywords:** conceptual blending, metaphor, Frame-based Terminology, predicate-argument structure, Frame Semantics

1. Introduction

Frame Semantics represents the meaning of words in terms of interpretive frames (Fillmore 1982, 1985; Fillmore and Atkins 1992, 1993). A frame is defined as a system of concepts that are related in such a way that one concept evokes the entire system. Based on this definition, Frame Semantics implicitly claims to be a theory of how concepts are organized and represented in the mind (Croft 2009: 8). The practical application of Frame Semantics is FrameNet (framenet.icsi.berkeley.edu), a lexical database that currently contains over 11,600 lexical units in more than 960 semantic frames. The aim of this resource is to document semantic and syntactic combinatorial possibilities of each word for all of its meanings.

We applied the tenets of FrameNet to specialized language, and analyzed the frames and semantic roles of *harmful algal bloom*, based on corpus data. Our analysis of the concept *harmful algal bloom* (HAB) situated it within a larger

Our analysis also accounted for the metaphorical meaning of the concept. There is a body of cognitive-linguistic studies that account for the metaphorical grounding of terminological units. For instance, Lakoff and Núñez (2000) analyze mathematical concepts on the basis of human experiences, which are metaphorical in nature. In this article, the metaphor numbers are physical segments allows us to characterize natural numbers, zero, and positive complex fractions (rational numbers) in terms of physical segments. Though insightful, studies of this type are restricted to the two-domain mappings advocated by Conceptual Metaphor Theory (Lakoff 1993).

Precisely for this reason, the need for representing figurative meaning from a frame-based perspective is long overdue. Frame Semantics has not as yet included links in FrameNet that reflect the metaphorical relation between domains (Ruppenhofer et al. 2010). To fill these gaps, this paper shows that the combination of FBT conceptual frames and conceptual blends (Fauconnier 1999; Fauconnier and Turner 1998, 2002) is well-suited for integrating cross-space (concretely, many-space) processing in environmental frames.

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2. Frames in terminology

Frames are applicable to specialized language as well as general language. A good example is BioFrameNet, which extends the Berkeley FrameNet lexical database to the domain of molecular biology. Dolbey (2009:iii) examines the syntactic and semantic combinatorial possibilities of the lexical items used in this domain to better understand the grammatical properties of specialized language. He also mentions that BioFrameNet could be used in natural language processing tasks, such as automatic semantic role labeling.

Frame-Based Terminology (FBT) uses frames as well to model the conceptual event structure of the environmental domain (Faber et al. 2005, 2006, 2007; Faber 2011). However, unlike BioFrameNet, FBT frames are more conceptual than semantic in nature, as shall be seen in this research study. The practical application of FBT is EcoLexicon, a multimodal terminological knowledge base (http://ecolexicon.ugr.es), in which environmental concepts are integrated in category templates. Each frame is composed of generic categories (e.g. process, agent,
Frame blending in specialized language

PATIENT, RESULT, INSTRUMENT, DISCIPLINE, etc.), which are interrelated within an event (see Figure 1). In this resource, the semantic structure of environmental concepts is based on information extracted from meaning definitions as well from a corpus of specialized texts (Faber et al. 2007: 41). This semantic analysis generates concept hierarchies and configures concepts in frames based on inheritance and subframe relations. The Environmental Event (Figure 1) is thus conceived as a dynamic process initiated by a natural or human agent, which affects a patient and produces a result.

The notion of dynamic conceptualization is central to Terminology theory (Faber 2011). However, this dynamicity is rarely reflected in the representation of specialized knowledge units, which are more closely related to general knowledge than previously assumed. For example, L’Homme and Polguère (2008: 27) identify seven types of relationships between terms and general language units, and make suggestions as to how to take these specific cases into account in general language dictionaries and databases. Pimentel et al. (2011) also address the problem of how to enrich lexical resources with meanings that belong to specialized knowledge domains.

The fact is that both general and specialized knowledge units can be studied with the same semantic approach since in both cases meanings are the result of a dynamic process of meaning construction, which can be explained by using frame

Figure 1. The environmental event frame
semantics and conceptual blending. As a matter of fact, this paper shows that dynamic conceptualization is an important aspect of the blended frames that generate the specialized knowledge concept of harmful algal bloom. It also reflects the relevance of figurative language and analogical thought for specialized concept description and comprehension.

3. Frames, mental spaces and blends

In Cognitive Linguistics, mental spaces are a proposal for conceptual description. According to Fauconnier (1994, 1997), counter-connections are established between mental spaces by means of projections of conceptual materials. These connections help to construct meaning through analogy, metaphor, and concept combination. Lakoff and Sweetser (in Fauconnier 1994: x–xi) argue that mental spaces, idealized cognitive models (ICMs), and frames can be integrated into a whole. In fact, frames and ICMs provide relational structure linking semantic roles in mental spaces. This paper explains how such roles can bring mental spaces and frames together, as exemplified in harmful algal bloom (HAB).

The relationship between frames and mental spaces is also reflected in research on Blending Theory (Fauconnier 1999; Fauconnier and Turner 1998, 2002; Coulson 2005; Coulson and Oakley 2006; Coulson and Pascual 2006). Inspired by Conceptual Metaphor Theory (Lakoff 1993; Lakoff and Johnson 1980, 1999), Blending Theory accounts for the pragmatic dimension of conceptual metaphor. As such, it inherits the mental space model and its concern with the dynamic aspects of meaning construction.

Blends are also dynamic in nature since they arise from the interaction of dynamic conceptual networks. Dynamism is intrinsically linked to novelty because both evoke the notion of conceptual structure that emerges on-line. As shall be seen, HARMFUL ALGAL BLOOM is largely conceptualized by dynamic cognitive patterns in the environmental event frame, which builds on an action-environment interface (Barsalou 2003; Faber et al. 2005; Faber 2011). Our study shows that HARMFUL ALGAL BLOOM is a conceptual blend.

4. Materials and methodology

4.1 Corpus selection and description

The first step was to analyze how HARMFUL ALGAL BLOOM is activated in specialized discourse. For this purpose, we compiled a corpus of marine biology texts,
namely, journal articles as well as two books for researchers and graduate students. The articles were published in high-impact scientific journals, most of which are indexed in the Journal Citation Reports website (see Table 1).

The two books were Ecology of Harmful Algae (Granéli and Turner 2007) and Cyanobacterial Harmful Algal Blooms (Hudnell 2008).

There is some debate regarding whether knowledge can be extracted by means of linguistic analysis. Roche (2007: 47–56), for instance, argues that not all relevant knowledge can be obtained from a textual corpus. An in-depth discussion of whether corpus data analysis can provide a full description of a conceptual domain is an issue that is beyond the scope of this article. Nevertheless, it cannot be denied that corpus analysis, when based on sound semantic theoretical premises, has yielded convincing results in the form of robust databases and ontologies. The OncoTerm database (http://www.ugr.es/~oncoterm/alpha-index.html) is a case in point. The Ecolexicon knowledge base is another example.

<table>
<thead>
<tr>
<th>Academic journals</th>
<th>Articles</th>
<th>Tokens per article (in parentheses)</th>
<th>Occurrences of harmful algal bloom(s) and HAB(s) per article (in parentheses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Malacological Bulletin</td>
<td>2</td>
<td>3,064 + 5,206 (8,270)</td>
<td>14 + 29 (43)</td>
</tr>
<tr>
<td>Biological Bulletin</td>
<td>2</td>
<td>20,980 + 15,178 (36,158)</td>
<td>58 + 39 (97)</td>
</tr>
<tr>
<td>Ecological Studies</td>
<td>1</td>
<td>3,319</td>
<td>49</td>
</tr>
<tr>
<td>Environmental Health</td>
<td>3</td>
<td>5,843 + 7,236 + 2,563 (15,642)</td>
<td>87 + 54 + 20 (161)</td>
</tr>
<tr>
<td>Estuaries</td>
<td>1</td>
<td>9,328</td>
<td>85</td>
</tr>
<tr>
<td>Harmful Algae</td>
<td>3</td>
<td>6,574 + 2,247 + 3,451 (12,272)</td>
<td>33 + 22 + 10 (65)</td>
</tr>
<tr>
<td>Hydrobiologia</td>
<td>3</td>
<td>2,963 + 2,307 + 2,714 + (7,984)</td>
<td>31 + 18 + 14 (63)</td>
</tr>
<tr>
<td>Journal of Applied Phycology</td>
<td>3</td>
<td>4,219 + 2,931 + 4,218 (11,368)</td>
<td>41 + 15 + 38 (94)</td>
</tr>
<tr>
<td>Journal of Industrial Microbiology and Biotechnology</td>
<td>1</td>
<td>11,816</td>
<td>102</td>
</tr>
<tr>
<td>Marine Pollution Bulletin</td>
<td>1</td>
<td>1,149</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>117,306</td>
<td>775</td>
</tr>
</tbody>
</table>
4.2 Semantic analysis of harmful algal bloom

As previously mentioned, a frame is a network of interconnected concepts that is activated by a linguistic item and the units in its co-text. In our study, we analyzed the argument structure of the verbal predicates that most frequently occur with harmful algal bloom (HAB) in our corpus in order to specify the semantic roles of HAB as well as its frames. In specialized language, verbs can provide valuable information concerning nouns and deverbal nominalizations in scientific texts. Key semantic data can be retrieved through the analysis of knowledge-rich contexts. Such contexts highlight salient conceptual characteristics of the search term (Meyer 2001: 280) and provide information that points to relations between concepts (L’Homme et al. 1999: 32–33).

4.2.1 Semantic roles

Specialized knowledge representation naturally includes semantic properties that help to describe the nature of objects and events. There is, however, a set of relations that has a special semantics. These relations describe connections between events and objects or other events. In linguistic terms, this is reflected as the relation between a verb and its arguments, which are typical roles that are activated by the predicate.

Semantic roles generally express the set of properties which a verb entails for a given argument. Although most linguists tend to believe that they exist, there is considerable disagreement as to their number, nature, and function. The question inevitably arises of how abstract or specific semantic roles should be. According to Van Valin (2004), semantic roles have been studied at three levels of generality: (i) verb-specific roles; (ii) thematic relations, which are generalizations across verb-specific roles; (iii) semantic macroroles, which are generalizations across thematic relations.

In FrameNet, semantic roles are verb-specific and frame-specific, and are hierarchically related within frames (Matsubayashi et al. 2009). Although the role hierarchy in individual frames was expected to generalize semantic roles, this does not seem to have happened (Baldewein et al. 2004). The generalization of semantic roles across different frames has thus become a critical issue for FrameNet (Gildea and Jurafsky 2002; Shi and Mihalcea 2005; Giuglea and Moschitti 2006).

The main issue is how much is too much and how little is too little. If the inventory of roles is open-ended, then the roles have no general descriptive adequacy. If the inventory is too restrictive, then it is not sufficient to describe the complexity of meaning. Evidently, there should be an explicitly defined inventory of semantic roles for a subset of reality. This inventory should be well defined, though not overly restricted. The set of semantic roles in this study largely coincides with the
most general ones in FrameNet. Others are taken from the inventory proposed by Gildea and Jurafsky (2002) and still others from the set of semantic roles in VerbNet (http://verbs.colorado.edu/semlink), which can also be partially mapped onto FrameNet roles (Matsubayashi et al. 2009). Table 2 is a non-exhaustive list of these roles.

4.2.2 The semantic roles of harmful algal bloom
The lexical analysis tool, Wordsmith Tools™ was used to obtain contexts for harmful algal bloom. Concordances were thus generated for bloom(s), harmful algal bloom(s), HAB(s), harmful algae, and HA(s) and converted into more extended contexts, which included the predicate-argument structures in which harmful algal bloom was embedded.

4.2.2.1 Harmful algal bloom as an agent. The corpus data revealed that harmful algal bloom (HAB) is generally conceived as an agent. As such, it initiates natural processes, which in turn have an effect on or produce a result in another entity, as shown in (1) and (2).

<table>
<thead>
<tr>
<th>Semantic role</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGENT</td>
<td>Entity that causes an action. It can be a natural agent (i.e. a natural force) or a human agent that carries out the action with intentionality.</td>
</tr>
<tr>
<td>CAUSE</td>
<td>Inanimate entity that can cause an action without intentionality</td>
</tr>
<tr>
<td>CREATOR</td>
<td>Entity that produces or causes another entity to exist by using self-produced or alien elements.</td>
</tr>
<tr>
<td>CREATION</td>
<td>Entity that is produced by a CREATOR.</td>
</tr>
<tr>
<td>USER</td>
<td>Entity that employs an INSTRUMENT to perform an action.</td>
</tr>
<tr>
<td>INSTRUMENT</td>
<td>Object used to carry out an action. INSTRUMENT generally refers to the tools, machinery, and devices that are used to carry out human process events in the environment. However, natural entities can also use natural instruments.</td>
</tr>
<tr>
<td>PATIENT</td>
<td>Entity that is affected by an event or process.</td>
</tr>
<tr>
<td>LOCATION</td>
<td>Underspecified destination, source, or place</td>
</tr>
<tr>
<td>THEME</td>
<td>Used for participants in a location or undergoing a change of location/possession.</td>
</tr>
<tr>
<td>RESULT</td>
<td>Entity/event that has come about as a consequence of a voluntary/involuntary action that is not CREATION.</td>
</tr>
<tr>
<td>PURPOSE</td>
<td>Objective of an AGENT when performing an action.</td>
</tr>
</tbody>
</table>

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(1) Phytoplankton need to remain close to the ocean’s surface in order to capture sunlight for photosynthesis. If the surface becomes depleted of nutrients required for growth, certain types of phytoplankton will be favored. For example, most marine HABs are dinoflagellates, which are distinguished by the presence of two flagella used for swimming. (Environmental Health, 7 (Suppl. 2), 2008)

In the analysis of context (1), phytoplankton is the generic term comprising a variety of algal blooms, such as diatoms, cyanobacteria, and mostly, dinoflagellates, as mentioned in (1). Thus, if phytoplankton species capture sunlight for photosynthesis, this means that harmful algal blooms do so as well. The predicate capture encodes an event that involves an entity taking another entity into possession. In FrameNet, capture is included in the conquering frame, which describes a theme losing its autonomy and perhaps sustaining material damage as the result of a successful invasion by a Conqueror. As evidenced by its arguments, capture in (1), as a general language verb, has been redeployed in a specialized context. The predicate-argument structure of this context is given in Table 3.

<table>
<thead>
<tr>
<th>Explicit predicate-argument structure</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>capture (HABs)<em>{agent} (sunlight)</em>{theme} (ocean’s surface)_{location}</td>
<td>HABs is an agent because HABs are animate entities that voluntarily instigate the action of capturing sunlight. Sunlight is a theme because it denotes an entity which becomes possessed by HABs.</td>
</tr>
</tbody>
</table>

As can be observed, the semantic role of Conqueror has been changed to the more general role of Agent. This is a better fit for a type of capturing involving the recruitment of packages of photons or sunlight (Theme) by HABs, which convert the photons into carbohydrate chemical bonds. Furthermore, the role of Agent is more appropriate in this case because it is one of the roles used in the frame-blend structure (see Section 4.2). Finally, the ocean’s surface (Location) is a non-core frame element.

The second predicate in which harmful algal bloom often appears as an agent is produce, as shown in (2).

(2) So-called harmful algal bloom taxa produce paralytic toxicants that inhibit metazoan nerve conduction (Cembella, 1998), such as the saxitoxins (Hall et al., 1990). (Biological Bulletin, 198, 2000, 225–244)

Produce is an action that results in the existence of a new entity. In FrameNet, produce (in this sense) belongs to the intentionally_create frame in which a
Creator creates a new entity. The intentional action of the Creator evidently means that this role can be regarded as a subtype of the more general Agent role (see Table 4).

Table 4. Argument structure of produce

<table>
<thead>
<tr>
<th>Predicate-argument structure</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODUCE (harmful algal bloom taxa) \textit{creator} (paralytic toxicants) \textit{creation}</td>
<td>HABs are creators because they cause paralytic toxicants (material entities) to exist by using self-produced molecules. Thus, toxicants are HABs’ creation.</td>
</tr>
</tbody>
</table>

In (2), \textit{harmful algal bloom taxa} have the Creator role. However, the action of causing \textit{toxicants} to exist (creation) is more complex since it takes place over time and involves several stages, such as activated reactions, chemical signaling, and discharge.

Context (3) also shows that \textit{harmful algal blooms} are agents that cause natural processes.

(3) There are also numerous examples in geographic regions ranging from the largest and second largest U.S. mainland estuaries […] where increases in nutrient loading have been linked with the development of large biomass \textit{blooms}, leading to anoxia (oxygen depletion). (Estuaries, 25(4), 2002, 704–726)

In this context, \textit{lead to} is similar to \textit{produce}. However, in this example, \textit{blooms} are regarded as a process (acting as an Agent), which results in another process. In FrameNet, \textit{lead to} belongs to the causation frame. In this case, a Cause (or actor standing in for the cause) causes an Effect. In this specialized language context, \textit{lead to} is a process linked to the activity of the blooms’ development. It takes place over time, since it involves HABs releasing CO$_2$ and intaking DO, a bounded activity that results in oxygen depletion. Rather than Effect, the semantic role of Result is more appropriate here. The predicate-argument structure of (3) is given in Table 5.

Table 5. Argument structure of lead to in context (3)

<table>
<thead>
<tr>
<th>Predicate-argument structure</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{lead to} \textsuperscript{2} (blooms) \textit{agent} (oxygen depletion) \textit{result}</td>
<td>\textit{Blooms} is an agent because it refers to animate entities that voluntarily deplete oxygen to develop. Oxygen depletion is the result (consequence) of HABs’ release of CO$_2$ and intake of DO.</td>
</tr>
</tbody>
</table>
HABS can also be agents that affect a number of entities, which become patients, as reflected in (4).

(4) Dinoflagellates are occasionally noticed as red tide causative organism, since their blooms seriously injure fisheries and human beings (Marine Pollution Bulletin, 23, 1991, 185–188)

Injure refers to when one entity damages or negatively affects another. In FrameNet, this verb belongs to the cause_harm frame, defined as a situation in which an Agent or a Cause injures a Victim or one of his/her body parts. In (4), however, injure is an action that refers to the continuous negative influence of HABS on marine fauna and flora and on humans. The role of Victim has been changed to the more general role of Patient. The predicate-argument structure of (4) is given in Table 6.

Table 6. Argument structure of injure in (4)

<table>
<thead>
<tr>
<th>Predicate-argument structure</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>injure (blooms)_agent (fisheries and human beings)_patient</td>
<td>Fisheries and human beings are labeled patient because these entities undergo a change of condition (they get sick, and sometimes, they even die) caused by HABs, which are an agent.</td>
</tr>
</tbody>
</table>

Finally, the corpus data show that HABs produce a series of results in the patients.

(5) Coastal waters of the United States (U.S.) are affected by many of the major harmful algal blooms (HABs), which cause poisoning syndromes and impacts. These include paralytic shellfish poisoning (PSP), neurotoxic shellfish poisoning (NSP), amnesic shellfish poisoning (ASP), ciguatera fish poisoning (CFP) and various other HAB phenomena such as fish kills, loss of submerged vegetation, shellfish mortalities, and widespread marine mammal mortalities (Harmful Algae, 8(1), 2008, 39–53).

In this sense, affect is a more general version of injure, in the same way as cause is a more general version of lead to. This is evident in the predicate-argument structure of context (5) given in Table 7.

The corpus data in the next section show that HAB can take semantic roles other than agent and creator, which enriches the conceptual description of HAB.
Table 7. Argument structure of affect and cause in context (5)

<table>
<thead>
<tr>
<th>Predicate-argument structure</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFFECT (harmful algal blooms)\textsubscript{agent} (coastal waters of the United States)\textsubscript{patient}</td>
<td>Coastal waters of the United States is a patient, because these waters undergo a change of condition caused by HABs, which are thus labeled agents.</td>
</tr>
<tr>
<td>CAUSE (harmful algal bloom)\textsubscript{agent} (poisoning syndromes, impacts: fish kills, loss of submerged vegetation, shellfish mortalities, marine mammal mortalities)\textsubscript{result}</td>
<td>As agents, HABs voluntarily produce toxins. The consequences that these toxins have for marine life and humans are thus the result of this production.</td>
</tr>
</tbody>
</table>

4.2.2.2 Harmful algal bloom as a natural process, result and patient. Further semantic features of HAB found in the concordances also revealed the multi-dimensional nature of this concept (Bowker and Meyer 1993; Bowker 1997). This means that HAB can fit into different generic categories of the environmental event frame, depending on the focus adopted. The multi-dimensionality of HAB is proof of the constantly changing nature of the interacting components of environmental subframes and is decisive in activating different types of blended frames that give rise to the concept (see Section 5.2).

The corpus data revealed that the proliferation of HABs can be a natural process and that a HAB can even be a natural process in itself (see context 6). This is a case of metonymy, in which the result stands for the process. The result (a large number of harmful algae) refers to the process that produced the algae (rapid and uncontrollable increase, that is, the action of blooming/proliferating).

(6) Eutrophication is one of several mechanisms by which harmful algae appear to be increasing in extent and duration in many locations. Although important, it is not the only explanation for blooms or toxic outbreaks (Estuaries, 25(4), 2002, 704–726).

Increase refers to when an entity becomes greater in number. In FrameNet, this verb belongs to the frame change\_position\_on\_a\_scale, defined as the change of an Item’s position on a scale (the Attribute) from a starting point (Initial value) to an end point (Final value). In this sense, harmful algae are the agents of the blooming process, which involves their increase and growth in both time and space. The predicate-argument structure of context (6) is reflected in Table 8.

HABs can also be the result of a series of factors, such as a higher water temperature, abnormal salinity levels, heavier rainfall, excessive loads of nutrients coming from waste spills (anthropogenic loadings), and water upwellings. These conditions benefit organisms that result in harmful blooms (see context 7).
Oceanic and estuarine circulation and river flow greatly influence the abundance and distribution of plankton and the combined physical (e.g., currents, upwelling, etc.) -chemical (e.g., salinity, nutrients, etc.) factors of these systems [...] result in blooms that impact coastal ecosystems and populations. (Journal of Industrial Microbiology and Biotechnology, 30, 2003, 383–406)

Result in focuses on the end or result of a causing process and belongs to the causation frame. According to FrameNet, the causing entity can be conceived of as a Cause, Actor, or Agent. The emergence of a HAB involves a set of subprocesses that occur in stages. These subprocesses mainly include the transport of substances in and out of cells, algal growth, and the establishment of aggregations for sexual exchange (Figueiras et al. 2006). The predicate-argument structure of (7) is given in Table 9.

<table>
<thead>
<tr>
<th>Predicate-argument structure</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESULT (upwelling, salinity, nutrients)&lt;sub&gt;cause&lt;/sub&gt; (blooms)&lt;sub&gt;result&lt;/sub&gt;</td>
<td>Upwelling (of nutrients) and salinity are Causes because they involve involuntary actions carried out by inanimate entities (tides and runoffs, respectively), which give rise to blooms. Blooms is a RESULT because it is the consequence of salinity and upwelling of nutrients to the sea surface.</td>
</tr>
</tbody>
</table>

Finally, a HAB can be a patient because it undergoes a change of condition when prevented, controlled, and mitigated, as shown in contexts (8) and (9).

(8) This paper summarizes past and present research and strategies for the prevention and control of K. brevis blooms. Prevention presumes a certain level of understanding about the cause or causes of these blooms. (Harmful Algae, 8(4), 2009: 623–628)
Flocculants have been used as HAB mitigation agents. Clay is one of the promising agents for HAB mitigation and control, if its environmental effects are minimized. (Ecology of Harmful Algae, 2007: 335)

The semantic analysis of the corpus examples provided us with key data about harmful algal blooms and permitted us to identify the conceptual dimensions of HAB, and assign it and its semantically related concepts to their corresponding frame slots of the environmental event (see Section 5.1).

### 4.3 The metaphorical nature of harmful algal bloom

Low (1999) argues that criteria for metaphor identification can be adopted from either an analyst-centered approach or a user-centered approach. In this study, we adopted the perspective of the analyst without considering the perspective of the users (in this case, marine biology experts). Our reasons for this were the following: (i) marine biology experts may not be aware that the term HAB is metaphorical; (ii) the cognitive projections that give rise to this concept in the blended frames are not entrenched, but rather are novel mental integrations.

Our method of metaphor identification involved specifying the motivation for metaphorical transfer of the term by applying a three-step procedure similar to that followed by the Pragglejaz Group (2007). This procedure contrasts the metaphorical meaning of a lexical unit in a particular context with its non-metaphorical meaning in other contexts. The steps in this process are the following:

1. Determination of whether the metaphor candidate has a more basic meaning in contexts apart from the domain-specific one.
2. Comparison of the basic meaning of the metaphor candidate with its meaning in a specialized context.
3. Determination of whether this comparison reflects semantic tension and if this semantic tension leads to referential incongruity (Caballero 2006) or to a domain shift (Charteris-Black 2004). If that is the case, then the candidate is an instance of terminological metaphor.

When determining the figurative meaning of specialized language units, a dictionary can be used as a norm of reference regarding word meaning for a particular group of users (Steen 2007: 97). The lexicographical and terminological resources used in our study were the American Heritage Dictionary of the English Language and the on-line marine biology database SeaLifeBase (http://www.sealifebase.org).

Initially, it was concluded that blooming has a basic meaning as well as a domain-specific meaning. The American Heritage Dictionary of the English Language defines bloom as “to grow or flourish with vigor”. The SealifeBase glossary refers to
harmful algal bloom as “a rapid increase in abundance of unicellular algae, reaching high densities, clearly visible to the naked eye (usually around 5,000,000 cells/L or more).”

The second step involved the comparison of the basic sense of bloom, flourishing with vigor with the terminological one, rapid increase in abundance. This reflected the semantic tension between both senses (blossoming vs. proliferation), and revealed that the aspects of thriving development are the basis of the metaphorical motivation.

The referential incongruity arises because aquatic microorganisms do not produce flowers. Thus, there is a shift from the domain of plants to that of aquatic microorganisms,3 which enabled us to formulate the conceptual metaphor rapid proliferation is blooming. This conceptual metaphor is reflected in biology terminology and discourse in the form of bloom.

The corpus data also helped to identify the metaphorical nature of HAB by providing the definitions of this term, which support the definition found in SeaLifeBase, as shown in (10):

(10) A harmful algal bloom in Florida is defined by a sudden increase in cell count of the causative organism above normal background levels. (American Malacological Bulletin, 21, 2006, 11–15)

Once the metaphorical nature of HAB was attested, this concept was then situated in the environmental event frame. After this, the subframes of the event were combined with conceptual blends to highlight its analogical basis.

5. Results and discussion

5.1 Situating harmful algal bloom in the environmental event frame

The corpus data featuring HAB showed that agent is the semantic role that activates the highest number of semantically-related concepts in the event frame. For this reason, Figure 2 depicts hab as an agent. As shown in Figure 2, a knowledge-rich context analysis provided the environmental subframes (in bold) with new subcategories. These and the rest of categories are explained below.

- A HAB is a biological natural agent, a subcategory which should be added to the natural agent template.
- The natural processes prompted by HABs are movement and accretion of toxins as well as loss of oxygen. Still another natural process subcategory, which should also be added to the template, is the physicochemical one. This includes the process subtemplates change of quality, represented by water discoloration,
and *thriving conditions*, which refers to any process furthering the development of aquatic life, such as *photosynthesis*.

- The patients of the natural processes are aquatic flora and fauna, humans, and water mass.
- The result template includes new subcategories, such as (i) flora and fauna, which have suffered harm or death; (ii) humans afflicted by diseases or socio-economic problems.
- The location template should also include the subcategory *lakes* since blooms have been reported to frequently occur in fresh and brackish water as well as marine lakes.

The contexts show a number of semantic roles (underlined in Figure 2) that also modulate the macro-categories of the event frame. For instance, *HAB* has an agent role, but it can also play more precise roles, such as creator (context 2).

Non-hierarchical conceptual relations (e.g. cause-effect, affected_by, and located_at) are important in modern approaches to terminological description (Meyer 2001; Faber et al. 2006). According to Faber (1999), these relations are essential for dynamic knowledge representations because they enhance conceptual structure by enriching networks and encoding dynamic relations between concepts. The basic non-hierarchical relations of *HAB* with its semantically related concepts are represented by the arrows below the frames in Figure 2.

### 5.2 Blending environmental subframes

Dictionary and corpus evidence show that *HAB* is a metaphorical term, as reflected in the comparison of its basic meaning (*flourishing with vigour*) and its domain-specific meaning (*rapid increase in number*). The metaphorical sense of this term is thus conventionalized in biology terminology and is the designation of a natural process. In contrast, conceptual blending portrays *hab* as the result of a series of sequential processes effected by agents in environmental subframes. It is these processes and agents as well as their outer-space vital relations (Fauconnier and Turner 2002) — material projections between different input spaces — that interact to produce the blend (see Figures 3 and 4).

This new blended representation of *hab* is sanctioned by its multidimensional nature since it can be classified from different conceptual viewpoints. Multidimensionality was first suggested in Terminology by Bowker (1997), and further described by Bowker and Meyer (1993). For instance, Bowker (1997, 133) argues that the concept *vehicle* can be classified not only as in terms of its transportation medium, but also in terms of its propulsion method and load carried. Multidimensionality is a crucial to terminology management, because
Figure 2. Non-hierarchical relations of HAB with its semantically related concepts and their location in the environmental event frame
it provides a more realistic view of the conceptualization and representation of specialized knowledge.

The possibility of belonging to several dimensions within a conceptual system links multidimensionality to the concept of domain matrix, which is the combination of multiple frames simultaneously invoked by a concept (Langacker 1987, 147). Accordingly, HAB can be described in terms of the following subframes (dimensions) of the environmental event (conceptual system): (i) physicochemical phenomena; (ii) aquatic microorganisms; (iii) health and socio-economic impacts. Figures 3 and 4 portray HAB as a physicochemical phenomenon or as the result of a series of processes in the blended space.

As shown in Figure 3, the environmental event templates and their constituents are included in the generic space of the integration network. The generic space contains information shared by the elements in the input mental spaces 1 and 2. These inputs also include the environmental templates and their frame elements. Input 1 shows the interactions between these frame elements, in other words, the entities and processes that affect plants and which result in blooming. Thus, input 1 contains the subframe plants, which in turn encompasses the agent, process, and patient templates. The interactions between the template elements are non-hierarchical relations and are dynamic patterns that streamline the action-environment interface.

Input 2 includes the entities and processes that affect aquatic microorganisms and cause them to bloom. The linguistic realizations of these entities and processes were identified by analyzing the distributional patterns of the predicate-argument structures in the corpus. The interactions between these entities and processes are profiled against the environmental subframe, aquatic microorganisms, which actively participates in the integration network and produces the subframe physicochemical phenomena inside the blended space.

Materials in inputs 1 and 2 are related by connectors that specify the connections between both spaces. These connectors correspond to analogical outer-space vital relations (see Figure 4). Accordingly, insects have the same function in the plant subframe as tides in the aquatic microorganism subframe. Similarly, pollen transport in the plant subframe is analogous to nutrient upwelling and runoffs in the aquatic microorganism subframe. The blended space is the result of the fusion or composition of the paired frame elements in the input spaces (e.g. pollen transport as nutrient upwelling).

Composition is completed by the recruitment or schema induction of background frames or pre-existing knowledge structures (Fauconnier 1997, 103). In this case, the background frames are thriving and vital development and present but unwanted, which provide the blend with further structure and prompt the emergence of additional materials. These materials are rapid proliferation,
provided by **thriving and vital development**, and *harmful*, provided by *present but unwanted* (see Figure 5). Both *rapid proliferation* and *harmful* are emergent because neither is present in the initial input spaces.

In the characterization of **HAB** as a blend, **thriving and vital development** and **present but unwanted** are correlates of the FrameNet frames **change_position_on_a_scale** and **cause_harm**, respectively. This shows the extent to which blending mechanisms and Frame Semantics are interrelated. In Figure 5, **thriving and vital development/change_position_on_a_scale** and **present but unwanted/cause_harm** are background frames, causing the concept **HAB** to exist by providing **BLOOM** with the emergent materials **rapid proliferation** and **harmful**. Figure 5 also contains the FrameNet frame causation, which is critical for the emergence of **BLOOM**. This frame connects the agent **sunlight** and the processes **substance transport**, **substance transportation**, and **photosynthesis** with **BLOOM** by means of the conceptual relation **causes**.

Focusing on **HAB** as a physicochemical phenomenon means using specific environmental subframes with their frame elements. One implication of this is that while the agents, processes, patients, and results are pre-existing constructs (tides, sunlight, pollen, plant, etc.), the outer-space vital relations between the mental spaces subsuming the subframes are not entrenched, but rather are novel mental connections for on-line processing. According to Blending Theory, on-line novel integration explains meaning construction. Thus, Figure 4 does not describe the conventionalized metaphorical projections underlying the concept of **BLOOM**, but rather the cross-space projections featuring prior phenomena that trigger the emergence of **BLOOM**, lexicalized as **pre-blooming stages**.

This type of outer-space connection is known as **analogy** (Fauconnier and Turner 2002). Analogy involves connecting two input spaces whose **roles** (abstract references) and **values** (role-fillers) (Fauconnier 1997, 108) or individual instances substantiating the roles are compressed by means of an inner-space relation. In this case, the relation is **identity**. The agent, process and patient frames in each of the input spaces are considered to be “frame-roles that are used to access [and identify] their values” (Fauconnier and Turner 2002: 257), namely, the frame elements (**sunlight**, **pollen transport**, **tides**, etc.). Analogy is eventually compressed into the inner-space vital relation **identity** in the blend. Accordingly, the connected materials in inputs 1 and 2 can be described as **analogues** because they share identity.

At the linguistic level, this identity can be expressed as a set of complex relations between agents, processes, and patients that give rise to blooming. Moreover, the fact that concepts such as **sunlight** and **photosynthesis** are shared by inputs 1 and 2 is a clear argument for non-metaphorical blended thinking. As Evans and Green (2006, 406) point out, connections giving rise to blended spaces apply not
only to metaphorical instances of meaning construction, but also to non-metaphorical instances.

Evidence can also be provided that this is a blend rather than a metaphor. According to Conceptual Metaphor Theory, the source domain (input 2) projects its structure onto the abstract target domain (input 1). However, it is evident that the causal framing of the target is preserved in our schema. As a matter of fact, the schema represents a *mirror network* (Fauconnier and Turner 2002), in which the spaces share a common frame or matrix, including the blend.

In our network, both input spaces contain the frames *agent, process,* and *patient* as well as their non-hierarchical relations. This structure is projected onto the blended space, which includes the additional frames, *thrusting and vital development* and *present but unwanted* with the emergent concepts *rapid proliferation* and *harmful,* respectively. In any case, even if the analogy in Figures 3, 4, and 5 were regarded as a metaphor, image-schematic structure from the source domain is not a necessary part of metaphorical mapping since image-schematic structure from the target domain can be part of the metaphorical mapping (cf. Croft 2009, 24–25).

Devising creative scenarios such as those in Figures 3, 4, and 5 is part of human reasoning, which relies on situated and dynamic simulations acting as an interface between cognition and perception (Barsalou 2003). The dynamic conceptualization of specialized knowledge has been discussed from a cognitive perspective. For example, Wright (2003) draws on Damasio’s (1994) model of concept formation to claim that specialized concepts are essentially instantaneous convergences of perceptual aspects that combine at a given point in time and space (Faber 2011).

In our study, by virtue of situatedness, *insects* could be replaced by other concepts, such as *birds* or *wind,* without disrupting the structure. This means that the outer-space connections established between inputs are instantaneous convergences that take the form of emergent and fleeting perceptions, which eventually allows for the formation of the concept HAB. Indeed, one of the objectives of the blended frames in this study is to provide further evidence that “the unrealistic cognitive models developed by blending actually facilitate the comprehension of scientific phenomena” (Coulson and Pascual 2006, 155). Accordingly, the set of creative connections in Figure 4 could facilitate the general comprehension of the causes of this natural phenomenon. In this sense, philosophers of science (Boyd 1993) and communication scientists (e.g. Knudsen 2003) support the claim that metaphorical and analogical thought is often used in problem-solving talk about popular science.
Figure 3. Material projections from the generic space onto the input spaces and relationships between materials within the environmental subframes in the integration network pre-blooming stages featuring BLOOM as a physicochemical phenomenon.
Figure 4. Outer-space vital relations in the integration network pre-blooming stages featuring BLOOM as a physicochemical phenomenon
6. Conclusions

This paper has explained how framing and blending can be combined to represent specialized figurative meaning. Evidence is provided that frames are an excellent tool to represent the dynamic processes that take place in specialized fields of knowledge in a way that is similar to human conceptual representation (Faber et al. 2007, 40). At the same time, this study provides insights into the relationships between conceptual frames. This is interesting because determining how frames interact is one of the practical matters of Frame Semantics that needs deeper consideration (Petruck 1996). Finally, as has been shown, conceptual blending is a valuable complement to frames, particularly when it comes to describing and explaining existing scientific knowledge. This reinforces the representational capacity of frames, which are characterized as a powerful kind of domain structure (Fillmore 1978, 165).
Notes

1. It should be noted that inheritance is not specific to Frame Semantics, and thus, to Frame-Based Terminology. There are other approaches to Terminology that also recognize the major role of inheritance. For instance, L’Homme (2004, 254ff.) speaks of hierarchical representation as one of the three “models of terminological data encoding”, together with the plain and the relational models. The hierarchical representation builds on “inheritance of properties”, which can be simple or multiple.

2. Metaphor is a classic case of verb-argument mismatch, and thus, poses a challenge to compositional approaches. In our view, one way to mark the metaphorical nature of lexemes is to use devious SRs, which reveal the semantic incongruity of metaphor. As context (3) shows, the metaphoric meaning of the verbal predicate lead to is indicated by devious SRs featuring its arguments. In this way, path, the natural SR of the first argument of lead to, has been changed to agent, implicitly indicating that lead takes on the meaning of cause. By the same token, goal, the natural SR of the second argument of lead, has been changed to result.

3. Focusing on phycological blooms, it could be suggested that the specialized concept bloom is also a metonymy because algae are one type of plants. However, although algae were once considered to be plants, they are now classified separately because they lack true roots, stems, leaves, and embryos (American Heritage Dictionary of the English Language).

4. Comparing HABs with plants and considering the negative impacts that HABs cause on humans and other complex organisms brings the ancient theory tradition of the Great Chain of Being into the picture. This tradition involves a purported natural hierarchy, which subordinates animals, plants, and inorganic entities (in this descending order) to human beings. This hierarchical structure has been shown to be the basis for an extensively exploited metaphor complex, involving downward and upward mappings (Krzeszowski (1997). In the mappings, negative aspects come from the lower organisms to higher organisms, whereas positive aspects go in the opposite direction. In the Great Chain, HABs are at lower level than plants, since HABs are more basic organisms. For this reason, HABs drag up negative aspects when the HAB-plant analogy is established. These aspects are the health problems and the socio-cultural impacts mentioned in this study.

References


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