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**Country Report**

# Biodiversity-related Content Currently Taught in Upper Secondary Biology in Japan - Especially Biodiversity -related Terms Found in Textbooks

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In the current Japanese Upper Secondary School National Curriculum Standard, biodiversity is one of the main learning topics in biological subjects, particularly in Basic Biology. As part of a study on teaching biodiversity in upper secondary school biology classes, we examined the treatment of biodiversity-related contents and terminology in currently used ten Basic Biology textbooks and five Advanced Biology textbooks. There were considerable differences in content about biodiversity, its frequency, and the terms used in these textbooks. In Basic Biology textbooks, 7 - 17% of the 150 - 240 text pages were allocated to biodiversity-related contents. Most textbooks covered all categories which Sakir and Kim (2021) proposed. The number of biodiversity-related terms in each textbook ranged from 41 - 71, of which 20 - 44 were listed in the index, and 8 - 18 were treated as key terms. Key terms common to most textbooks were biodiversity, species diversity, alien species, endangered species, extinction, ecosystem services, and environmental impact assessment. In the Advanced Biology textbooks, the pages allocated to biodiversity-related contents were only 2 - 5% of the 270 - 428 text pages. Some of these textbooks were missing some of Sakir and Kim's categories. The number of biodiversity-related terms in each textbook ranged from 33 - 56, of which 14 - 28 were listed in the index, and 7 - 13 were treated as key terms. Examples of major key terms used in Advanced Biology textbooks included biodiversity, genetic diversity, species diversity, ecosystem diversity, disturbance, Allee's effect, inbreeding depression, vortex of extinction, and ecosystem services. Based on our findings, we argue that textbook editors/authors need to give more consideration to contents, terminology, and the arrangement of topics pertaining to biodiversity to help students fully understand the importance of biodiversity conservation.

***Keywords:*** *Advanced Biology, Basic Biology, biodiversity-related terms, National Curriculum Standard, Japan, text-book survey, upper secondary school*

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## INTRODUCTION

Sakir and Kim (2021) presented their report on the biodiversity-related contents in secondary school biology textbooks from Korea, Indonesia, and the United States of America. In their paper, they wrote that they intend to carry out the same study on biology textbooks from other countries such as Japan in future study. They will possibly choose one Japanese biology textbook as they chose only one textbook from each country in their research. However, in Japan, there are 10 different Basic Biology textbooks (In fact, 11 different textbooks were published, two of which were identical in contents and only differed in book size. Therefore, we consider them to be of the same type.) and five

Advanced Biology textbooks published and used nowadays, and there is a considerable difference in the contents between them. Even if Sakir and Kim were to select one each among these textbooks which is mostly used in Japanese upper secondary schools, the survey results might only reflect a portion of biodiversity education being conducted at upper secondary schools in Japan.

In Japan, a detailed textbook survey was conducted into how biodiversity conservation had been taught in upper secondary school biology subjects under the Upper Secondary School National Curriculum Standard (USS-NCS), which was revised four times between 1970 and 1999 (Kato, 2016a, 2016b). Additionally, surveys have been conducted on the treatment of invasive alien species in upper secondary biology textbooks published in 2012 (Doi and Hayashi, 2015) and in 2014-2015 (Higa, 2019). The latest revision of the USS-NCS was carried out in 2018, and the contents of the biology subjects "Basic Biology" and "Advanced Biology" in the USS-NCS, have already been reported by Nakamichi *et al*. (2023). However, no report has yet been published on the topics related to biodiversity and its conservation that are being taught under the current USS-NCS framework. According to the current USS-NCS (MEXT, 2018), biodiversity is one of the most important topics to be taught in the subject area of biology, particularly in Basic Biology, which more than 90% of students take during their time in upper secondary school (this percentage is estimated by the method of Nakamichi and Katayama, 2018, by using the data provided by The Jiji Press, 2024).

To find out what topics related to biodiversity are currently being taught in upper secondary school biology subjects in Japan, we surveyed the contents and terminology related to biodiversity in the current USS-NCS (MEXT, 2018) and its Guidelines (MEXT, 2021) as well as in currently used Basic Biology and Advanced Biology textbooks. In the present paper, we mainly focus on the terms found in these surveyed materials. We also have investigated what content and how much detail is provided in textbooks regarding biodiversity and its conservation, and what kind of organisms are introduced in them. We will report these results in detail in the future.

## MATERIALS AND METHODS

### *USS-NCS and Its Guidelines*

These materials were downloaded from the MEXT website (See References).

### *Textbooks Surveyed*

There are five publishers (Daiichi Gakushusha Corp.; Jikkyo Shuppan Co., Ltd.; Shinkoshuppansha Keirinkan Co., Ltd.; Suken Shuppan Co., Ltd. ; Tokyo Shoseki Co., Ltd.) each of which has published two sorts of Basic Biology textbooks in 2022 and one Advanced Biology textbook in 2023 (See the list in the “Biology Textbooks Surveyed” section at the end of the text). For the convenience of the survey, we numbered textbooks.

Regarding Basic Biology textbooks, #01 and #02 are published by the same publisher, and the editors and authors of these textbooks are almost all the same. Similarly, a pair of textbooks #03 and #04, #05 and #06, #07 and #08, #09 and #10 are published by four different publishers (one for each pair), and the textbooks in each pair have almost the same editors and authors. (see Biology Textbooks Surveyed section at the end). Of the two Basic Biology textbooks published by each textbook publisher, one has easier contents than the other except for #05 and #06. In this paper, we call the former *E* (easy) edition, and the latter *O* (ordinary) edition.

***Determination of Biodiversity-related Contents and Terms***

For determining biodiversity-related contents and terms, we first referred to Kato's (2016a, 2016b) description on biodiversity, and the categorization of biodiversity and contents provided by Sakir and Kim (2021). However, there seemed to be some other topics related to biodiversity that were not included in their descriptions and categories. Thus, we listed terms found in the USS-NCS, its Guidelines, and Basic Biology and Advanced Biology textbooks that we thought were related to biodiversity. Any terms which described some relevance to biodiversity even if in only one textbook, were considered as biodiversity-related terms and the topics included these terms as biodiversity-related contents. These terms are shown in the table in the Appendix.

***Data Collection***

For the USS-NCS and its Guidelines, we searched terms related to biodiversity and examined what were described.

For textbooks, we collected and analyzed data in terms of the number of pages which include biodiversity-related contents, the number of biodiversity-related terms found in the text, and whether these terms were collected in the index and treated as key terms. In the textbooks, key terms were either grouped in the margins of the page or printed in bold in the text.

***Terminology***

When compiling the list of terms from the USS-NCS, its Guidelines, and textbooks, difficulties arose in translating Japanese terms into English. Sometimes a single term referred to two phenomena, but sometimes multiple terms with different Japanese spellings were used to refer to the same phenomenon.

As an example for the former, the USS-NCS and its guidelines used the same Japanese phrase SEIBUTSU NO TAYOUSEI to describe "the existence of organisms having a variety of different characteristics in the natural world" and "the degree of diversity of organisms in a certain area." However, some textbooks distinguished between the two, using SEIBUTSU NO TAYOUSEI and the compound term SEIBUTSU_TAYOUSEI to describe the former and the latter, respectively. Therefore, we distinguished them by using the terms, the diversity of organisms and biodiversity.

As an example for the latter, there were four different words/phrases for genetic diversity in biology textbooks as follows: IDENTEKI_TAYOUSEI, IDENTEKI NA TAYOUSEI, IDENSHITEKI_TAYOUSEI, IDENSHI NO TAYOUSEI. As the definitions of these words/phrases did not seem to be strictly the same, we distinguished the former two as genetic diversity and the latter two as gene diversity/the diversity of genes.

Thus, in the present paper, we have attempted to translate as closely as possible these terminological differences into English. Terminology issues are discussed in more detail in the Discussion section.

***Data Analysis***

For the convenience of data analysis, we classified the biodiversity-related contents and terms. To do so, we set three ranks of categories: superordinate categories, subordinate categories, and specific individual categories and classified each term found in the textbooks surveyed into the most appropriate specific individual category (See the table in the Appendix). For classifying these biodiversity-related terms, we referred to Sakir and Kim (2021). However, we did not follow their classification completely because their paper does not list all biodiversity-related terms, particularly there were no terms/examples for local biodiversity.

Therefore, our categorization and classification may be somewhat subjective, and thus our classification should be considered further.

In addition, the results of our survey are also somewhat subjective, since it is very difficult to determine whether various terms found in textbooks are related to "biodiversity," and whether it is necessary to distinguish between terms that are written in different Japanese spellings as described above.

We tried to find out whether Japanese biology textbooks contained topics that fit Sakir and Kim's (2021) categorization by referring to the terms listed in their report. However, the attempt was not completely successful because many terms found in Japanese textbooks were not found in their report.

## RESULTS AND DISCUSSION

### *Biodiversity Contents in USS-NCS and Its Guidelines*

According to the present USS-NCS (MEXT, 2018) and its Guidelines (MEXT, 2021), in Basic Biology, students are supposed to learn about the unity (commonality) and diversity of organisms in the first section "Unity and Diversity of Organisms" of Unit 1 "Characteristics of Organisms." In this section, the emphasis is on the commonality of living things, *i.e.*, that all living organisms have a lot of common characteristics because they descended from common ancestors. Furthermore, the diversity of organisms* in this unit does not indicate the same concept as biodiversity, since the term stresses that organisms are very diverse.

* From here on, biodiversity-related terms found in the USS-NCS and its Guidelines, as well as in biology textbooks, will be underlined.

Therefore, in Basic Biology, students learn about biodiversity (in the USS-NCS and its Guidelines, it was written as the diversity of organisms) in Unit 3 "Diversity of Organisms, and Ecosystems," particularly in the Chapter "Ecosystems and Their Conservation." In this chapter, there are two sections, "Ecosystems and Diversity of Organisms" and "Ecosystem Balance and Conservation." In the former section, it is recommended “to allow students to discover and understand the species diversity of organisms in ecosystems through observations and experiments on ecosystems and the diversity of organisms, and to relate and understand the species diversity and the relationships between organisms (MEXT, 2021).” In the latter section, it is recommended “to allow students to understand the relationship between ecosystem balance and artificial disturbance based on materials related to ecosystem balance, and to recognize the importance of ecosystem conservation (MEXT, 2021).” In addition, some related topics, such as the extinction of organisms and ecosystem disturbance by human activities which results in damaging the diversity of organisms, are recommended to be taught.

In the USS-NCS and its Guidelines, the content description for Advanced Biology does not indicate a specific chapter or section in which to teach biodiversity and related topics. Furthermore, there is no explanation about biodiversity-related topics, and no terms related to biodiversity other than conservation were found. Thus, we considered that biodiversity and its related topics possibly could be taught in Unit 5 "Communities and Their Environments" which comprises four chapters: "Populations," "Communities," "Matter Production and Cycle in Ecosystems," and "Ecosystems and Human Life."

Only seven biodiversity-related terms were found in the USS-NCS and its Guidelines. Among these terms, conservation was found

once in the content description for Advanced Biology while the other terms were found only in Unit 3 "Diversity of Organisms, and Ecosystems" of Basic Biology (Table 1).

***Biodiversity Contents in Basic Biology Textbooks***

Almost all topics related to biodiversity were dealt in the chapter "Ecosystems and Their Conservation" though in some textbooks a few biodiversity-related terms, such as the diversity of organisms, conservation, and extinction, were found and explained in the other sections. The number of pages allocated to this chapter ranged from 14 to 34, a difference of more than twofold among textbooks (Table 2). We simply compared the percentage of pages allocated to this chapter, but the comparison is not exact, because the size of these textbooks and the number of characters per page were not necessarily the same. Compared to the *O* edition from each publisher, the *E* edition had fewer pages of the main text, but the proportion of pages allocated to this chapter was slightly less or almost the same. Textbooks #03 and #04 published by the same publisher seemed to cover the topics in less detail than the others.

Most of the Basic Biology textbooks covered the topics that fit Sakir and Kim's (2021) categories except “biodiversity hotspots” (Table 3). As explained later, biodiversity hotspots were not included even in three Advanced Biology textbooks, and therefore a considerable number of students would have no opportunity to learn about this topic at upper secondary school. On “biodiversity measurement,” all textbooks mentioned environmental impact assessment which is an essential process for land development projects. Sakir and Kim (2021) reported that in the USA textbook there are three descriptions on biodiversity measurement, species richness, species evenness, and diversity indices. All Basic Biology textbooks referred to species richness as an indicator of biodiversity richness, and textbooks #03 and #04 mentioned species evenness, but no textbook referred to diversity indices.

***Table 1: Terms and number of their occurrences in Upper Secondary School National Curriculum Standard and its Guidelines****

| Terms | No. of occurrences |
|---|---|
| Diversity of organisms | 10 |
| Species diversity | 2 |
| Ecosystem balance | 3 |
| Disturbance | 1 |
| Artificial (anthropogenic) disturbance | 1 |
| Extinction | 1 |
| Conservation | 6 |

* The USS-NCS guidelines contain some sentences that entirely quote the contents of the USS-NCS, so terms that appear in the overlapping parts were not counted.

***Table 2: The number of main text pages and of chapter on “Ecosystems and Their Conservation” in Basic Biology textbooks***

| | Basic Biology Textbook (Number and edition) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | #01 *O* | #02 *E* | #03 *O* | #04 *E* | #05 | #06 | #07 *O* | #08 *E* | #09 *O* | #10 *E* |
| Main text* pages | 240 | 200 | 216 | 195 | 200 | 196 | 188 | 150 | 200 | 158 |
| Chapter on “Ecosystems and Their Conservation”** | 30 | 20 | 20 | 14 | 26 | 26 | 28 | 19 | 34 | 26 |
| Proportion*** | 13 | 10 | 9 | 7 | 13 | 13 | 15 | 13 | 17 | 16 |

* Excluding endpapers, table of contents, reference materials at the beginning and end of the book, index, and colophon

** Excluding summaries of terms and topics, and exercises.

***Table 3: Topics contained in Basic Biology textbooks that fit Sakir and Kim's (2021) categorization****

| Category | | Basic Biology textbook | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | #01 | #02 | #03 | #04 | #05 | #06 | #07 | #08 | #09 | #10 |
| Biodiversity definition | | ○ | △ | ○ | △ | ○ | ○ | ○ | ○ | ○ | ○ |
| Biodiversity level | Genetic | ○ | ○ | ○ | × | ○ | ○ | ○ | ○ | ○ | ○ |
| | Species | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| | Ecosystem | ○ | ○ | ○ | × | ○ | ○ | ○ | ○ | ○ | ○ |
| Biodiversity value | | ○ | ○ | ○ | ○ | ○ | ○ | ○ | △ | ○ | ○ |
| Cause of biodiversity loss | | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Biodiversity conservation | | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Biodiversity measurement | | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Biodiversity hotspots | | ○ | × | × | × | ○ | ○ | × | × | × | × |
| Local biodiversity | | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

* ○: related topic(s) presented and well-explained, △: related topic(s) presented but explained little, ×: no related topics

The USS-NCS and its Guidelines instruct that in Basic Biology species diversity of organisms should be mainly dealt within the diversity of organisms. Therefore, in all textbooks, species diversity with its explanation (definition) was found in the main text though some textbooks additionally gave an explanation or definition of biodiversity (or the diversity of organisms) in the main text. Two textbooks (#02 and #04), both are *E* editions, included the term biodiversity (or the diversity of organisms) in the main text, but did not provide its definition (Table 3). In the other textbooks, biodiversity (or the diversity of organisms) together with the three levels of biodiversity were explained in the reference or extension column. Among the other textbooks, the definition of biodiversity was somewhat different – this would be reported in detail in the future. In some textbooks the definition of biodiversity was insufficient or the difference in definitions between biodiversity (or species diversity) and the diversity of organisms was not clear. For example, textbook #03 it is explained that "there are a variety of environments and a variety of organisms are living there. The existence of a variety of organisms like this refers to biodiversity." Textbooks #05 and #06 contained an unexplained statement that "the diversity of organisms which comprise an ecosystem is called biodiversity." In such cases some students could be confused because they learned that "the diversity of organisms refers to the diverse characteristics of the organisms living on Earth" in Unit 1 "Unity and Diversity of Organisms." This might come from terminology (using the term the diversity of organisms for biodiversity) – this will be discussed further in the *Issues in Terminology* section. One textbook of *E* edition (#04) did not mention genetic diversity and ecosystem diversity at all (Table 3). Students can learn more about biodiversity in Advanced Biology classes, but not all students take Advanced Biology. Therefore, we consider that an accurate definition of biodiversity and the three levels of biodiversity, which is essential to understand biodiversity principles, need to be taught in Basic Biology.

The other terms (topics) mentioned in the

USS-NCS and its Guidelines, ecosystem balance, disturbance, extinction, and conservation were found in all textbooks, but for disturbance and conservation, some textbooks did not give any explanation or definition, possibly because these words are often used in daily life. Regarding artificial (anthropogenic) disturbance, only four textbooks used this term and gave an explanation, while the remaining textbooks did not use this term, instead using the explanatory term "disturbance caused by human activities".

Table 4 shows the number of biodiversity-related terms found in each Basic Biology textbook. The total number of biodiversity-related terms found in the ten textbooks was 113, but the number of mentions in the textbooks ranged between 41 and 71 (55 in average). The number of biodiversity-related terms collected in the index considerably ranged from 19 to 44 (28 in average) depending on the textbook, approximately one-third to half of the terms presented in the text. Among the terms found in each textbook, 8 to 18 (14 in average) terms were treated as key terms, that accounted for more than one-tenth to one-quarter of the terms found.

Terms that were treated as key terms in the majority (five or more) textbooks are shown in Table 5. Biodiversity, and species diversity + the diversity of species were treated as a key term by six textbooks, and genetic diversity and ecosystem diversity were by four textbooks. Among terms occur in the USS-NCS and its Guidelines, extinction and disturbance were treated as key terms by five or more textbooks. However, the number of textbooks which treated the terms ecosystem balance, artificial disturbance and conservation as key terms was only two, two and one, respectively.

Among terms which are not mentioned in the USS-NCS and its Guidelines, alien species was treated as a key term by all textbooks. However, only four textbooks treated native species (indigenous species), which is the opposite term of alien species, as a key term, while eight textbooks treated the term endangered species, which is included in the native species category, as a key term. In the previous USS-NCS and its Guideline, it was recommended that alien species be dealt with an example of a factor affecting local biodiversity (Higa, 2019), so this term might have remained as a key term in the current textbooks.

Most textbooks considered environment impact assessment, which related to the measurement and conservation of biodiversity, and ecosystem services, which we can receive more as a result of biodiversity conservation, to be important terms.

Rapid eutrophication and global warming are considered to be causes of biodiversity decline or loss. In Table 5, eutrophication ranked high on the list, along with cyanobacterial blooms and red tides, while water blooms, which are considered a higher level concept

***Table 4: The number of terms related to biodiversity found in each Basic Biology textbook***

| | Basic Biology textbook | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | #01 | #02 | #03 | #04 | #05 | #06 | #07 | #08 | #09 | #10 | |
| No. of terms found only in the text | 53 | 44 | 71 | 56 | 63 | 61 | 56 | 41 | 56 | 50 | 113 |
| No. of terms found in the text and index | 22 | 19 | 44 | 32 | 43 | 20 | 24 | 23 | 32 | 25 | 84 |
| No. of terms treated as key terms | 8 | 9 | 8 | 18 | 14 | 17 | 17 | 16 | 15 | 13 | 37 |

***Table 5: Biodiversity-related terms treated as key terms in Basic Biology textbooks***

| Terms | No. of text-books |
|---|---|
| Alien species | 10 |
| Environment impact assessment | 9 |
| Ecosystem services | 9 |
| Eutrophication | 8 |
| Endangered species | 8 |
| Extinction | 7 |
| Biodiversity | 6 |
| Species diversity + Diversity of species | 5 + 1 |
| Disturbance | 5 |
| Greenhouse effect | 5 |
| Greenhouse effect gases | 5 |
| Cyanobacterial blooms | 5 |
| Red tides | 5 |

than cyanobacterial blooms, ranked lower. Greenhouse effect and greenhouse effect gases were treated as key terms by five textbooks, but global warming, the result of greenhouse effect, was treated as key term by four textbooks.

***Biodiversity Contents in Advanced Biology Textbooks***

As mentioned above, the USS-NCS and its Guidelines do not indicate in which unit and chapter topics related to biodiversity should be dealt with in Advanced Biology. Therefore, using some keywords related to biodiversity, such as biodiversity (genetic diversity, species diversity, ecosystem diversity), ecosystem balance, extinction of species, native and alien species, and conservation, as probes, we tried to find chapters where biodiversity-related topics are described. As a result, in every Advance Biology textbook, most terms were found in Unit 5 "Communities and Their Environments," particularly in the chapter "Ecosystems and Human Life" (Table 6). Therefore, most of the topics related to biodiversity were considered to be described in this chapter.

The main text pages of each textbook exceeded 350 except for textbook #A2. The number of pages allocated to the chapter "Ecosystems and Human Life" ranged from seven to 20, and the apportion rate was 2 - 5% (Table 7); the values are smaller than those of Basic Biology textbooks. It is reasonable because, according to NCS-USS, the learning contents of Advanced Biology are considerably different from Basic Biology. However, from the viewpoint of biodiversity education, the number of topics to be described in detail in the text would be restricted.

The terms found in Unit 1 "Evolution" were diversity, biodiversity, the diversity of organisms, genetic diversity, the diversity of genes, endemic species, extinction (of organisms), and mass extinction. These were briefly described in

***Table 6: Number of biodiversity-related terms found in different units of Advanced Biology textbooks***

| | Advanced Biology textbook | | | | |
|---|---|---|---|---|---|
| | #A1 | #A2 | #A3 | #A4 | #A5 |
| No. of terms found in Unit 1* | 5 | 7 | 5 | 6 | 4 |
| No. of terms found in Unit 5** | 47 | 30 | 49 | 31 | 53 |
| No. of terms found in the chapter "Ecosystems and Human Life" | 40 | 26 | 43 | 29 | 49 |
| No. of terms found in the other Units*** | 6 | 1 | 2 | 8 | 4 |

* Unit 1: Evolution.

** Unit 5: “Communities and Their Environments” which includes the chapter "Ecosystems and Human Life."

*** The other units: Metabolic Activities, Gene Expression and Ontogeny, and Responses to Environmental Stimuli

***Table 7: The number of main text pages and of chapter on "Ecosystems and Human Life" in Advanced Biology textbooks***

| | Advanced Biology textbook | | | | |
|---|---|---|---|---|---|
| | #A1 | #A2 | #A3 | #A4 | #A5 |
| Main text* pages | 428 | 270 | 394 | 368 | 368 |
| Chapter on " Ecosystems and Human Life"** | 20 | 7 | 9 | 8 | 12 |
| Proportion*** | 5 | 3 | 2 | 2 | 3 |

* Excluding endpapers, table of contents, reference materials at the beginning and end of the book, index, and colophon.
** Excluding summaries of terms and topics, and exercises.
*** Percentage of pages for the chapter on "Ecosystems and Human Life" to the number of pages in the main text.

the chapter "Phylogeny and Evolution" of this Unit. However, biodiversity here is likely to mean the presence of a variety of organisms on the earth, though we are not certain whether it indicates biodiversity at the global level.

The terms biodiversity and its synonym, the diversity of organisms, genetic diversity and its synonym, the diversity of genes, and extinction occurred repeatedly in multiple units. Textbooks #A1, #A4 and #A5 mentioned biodiversity or genetic diversity in the chapter "Genetic Engineering" of Unit 3 "Gene Expression and Ontogeny" along with the Cartagena Protocol on Biosafety, an international framework regarding the use of genetically modified organisms.

Table 8 shows whether Advanced Biology textbooks contained topics that fit Sakir and Kim's (2021) categorization. For the categories marked with a triangle in Table 8, related terms were found but the explanation was deemed insufficient. For example, textbook #A3, which we considered to give an insufficient definition of biodiversity, stated that "A wide variety of organisms coexist on earth. Biodiversity can be viewed from three perspectives: not only species diversity, but also genetic diversity within a species and ecosystem diversity." Most of the Advanced Biology textbooks provided a sufficient definition of biodiversity and clearly explained its three levels: genetic diversity, species diversity, and ecosystem diversity. All textbooks also provided some examples of causes of biodiversity loss due to human activities, such as habitat fragmentation, global warming, and environmental pollution. However, other categories were not covered fully, possibly due to space constraints in the textbooks. As with the basic biology textbooks, the term, biodiversity hotspots, was found only in two textbooks. The description of local biodiversity seemed to be insufficient. Textbooks #A1 and #A3 mentioned Satoyama (countryside

***Table 8: Topics contained in Advanced Biology textbooks that fit Sakir and Kim's (2021) categorization****

| Category | | Advanced Biology textbook | | | | |
|---|---|---|---|---|---|---|
| | | #A1 | #A2 | #A3 | #A4 | #A5 |
| Biodiversity definition | | ○ | ○ | △ | ○ | ○ |
| Biodiversity level | Genetic | ○ | ○ | ○ | ○ | ○ |
| | Species | ○ | ○ | ○ | ○ | ○ |
| | Ecosystem | ○ | ○ | ○ | ○ | ○ |
| Biodiversity value | | ○ | △ | ○ | ○ | ○ |
| Cause of biodiversity loss | | ○ | ○ | ○ | ○ | ○ |
| Biodiversity conservation | | ○ | △ | ○ | △ | ○ |
| Biodiversity measurement | | △ | × | ○ | × | △ |
| Biodiversity hotspots | | × | × | ○ | × | ○ |
| Local biodiversity | | ○ | △ | △ | × | × |

* ○: related topic(s) presented and well-explained,
△: related topic(s) presented but explained little, ×: no related topics

forests) and stated that it is one of the places rich in biodiversity, but no further details are provided. Textbook #A1 mentioned some native species and textbook #A2 mentioned only endangered native species, while textbooks #A4 and #A5 did not mention this topic at all. In addition to describing the local biodiversity, textbook #A3 seemed to explain biodiversity measurement by mentioning environmental impact assessment better than the other textbooks. In the other textbooks, biodiversity measurement was referred only briefly or not at all.

As described above, most biodiversity-related terms were found in the chapter "Ecosystems and Human Life" of Unit 5 "Communities and Their Environments" though some terms, such as genetic diversity and the extinction of organisms along with its related terms (*e.g.*, mass extinction and extinction vortex), were also found in other chapters or units.

The total number of biodiversity-related terms found in five Advanced Biology textbooks was 89. Of these, 47 were found in the index and 24 were treated as key terms. There was a considerable difference in the number of terms found in each textbook (33 – 56) which indicates the differences in topics covered in each textbook. There was also a nearly two-fold difference between the number of terms found in the index and the number of terms treated as key terms between the textbooks (Table 9). There were 37 terms that occurred in at least one Basic Biology textbook but not in any Advanced Biology textbooks.

Terms occurred in all five textbooks were as follows: biodiversity, the diversity of organisms, genetic diversity, the diversity of genes, disturbance, the Intermediate Disturbance Theory, extinction, Allee's effect, inbreeding depression, global warming, eutrophication, overexploitation, conservation, and coral reefs (the places where a rich biodiversity occur, so they should be conserved). Species diversity or its synonym, the diversity of species, and ecosystem diversity or its synonym, the diversity of ecosystems, both or either, also occurred in all textbooks. Most of these terms were found in most Basic Biology textbooks, but Allee's effect was not, and inbreeding depression, overexploitation and coral reefs were only in some Basic Biology textbooks.

Biodiversity, disturbance, and the Intermediate Disturbance Theory were indexed in all textbooks among 47 terms found in the index of at least one Advanced Biology textbook. Relevant terms indexed by four textbooks were genetic diversity, Allee's effect, inbreeding depression, extinction vortex, eutrophication, ecosystem services, and those by three textbooks were alien species, global warming, and greenhouse effect gases.

Terms treated as key terms by three or more textbooks are shown in Table 10. Only the term

***Table 9: The number of biodiversity-related terms found in each Advanced Biology textbook***

| | Advanced Biology textbook | | | | | Total |
|---|---|---|---|---|---|---|
| | #A1 | #A2 | #A3 | #A4 | #A5 | |
| No. of terms found only in the text | 49 | 33 | 54 | 38 | 56 | 89 |
| No. of terms found in the text and index | 25 | 14 | 28 | 14 | 16 | 47 |
| No. of terms treated as key terms | 13 | 12 | 13 | 9 | 7 | 24 |

the Intermediate Disturbance Theory, which refers to the idea that ecosystems experience the highest diversity and stability at intermediate levels of disturbance (Dial and Roughgarden, 1998; this idea is generally called as the Intermediate Disturbance Hypothesis) , was treated as a key term in all textbooks. Among Basic Biology textbooks, only two (#5 and #6) published by the same publisher mentioned this idea as the Intermediate Disturbance Hypothesis and treated the term as a key term. Biodiversity and its three levels were treated as key terms by four textbooks. However, one textbook (#A5) treated only biodiversity as a key term, and another textbook (#A3) treated genetic diversity, species diversity and ecosystem diversity as key terms, but not actual biodiversity. The same as in Basic Biology, disturbance and ecosystem services appear to be important terms in Advanced Biology. Allee's effect, inbreeding depression, and extinction vortex were treated as key terms in three textbooks. These terms are related to species extinction, and while population extinction and species extinction occurred in some textbooks, they were not treated as key terms. In addition, habitat fragmentation and population isolation, which trigger this phenomenon, were only found in the indexes of two textbooks, and only one textbook treated the former as the key term, indicating that overall, they are not given much importance.

Other examples of the strangeness of the selection of key terms include, in one textbook, the term ecological corridor, a conservation method to avoid habitat fragmentation, was treated as a key term, though the term habitat fragmentation occurred in the text but not even in the index. In another textbook, the term, tidal flats, was treated as a key term, but the term, wetlands, which is a higher-level concept (Convention on Wetlands Secretariat, 1971), was not even included in the index, although the term occurred in the text.

***Table 10: Biodiversity-related terms treated as key terms in Advanced Biology textbooks***

| Terms | No. of textbooks |
|---|---|
| Intermediate Disturbance Theory | 5 |
| Biodiversity | 4 |
| Genetic diversity | 4 |
| Species diversity + the diversity of species | 2 + 2 |
| Ecosystem diversity + the diversity of ecosystems | 2 + 2 |
| Disturbance | 4 |
| Ecosystem services | 4 |
| Allee's effect | 3 |
| Inbreeding depression | 3 |
| Extinction vortex | 3 |

***Selection and arrangement of topics related to biodiversity***

Most of Basic Biology textbooks covered all categories mentioned by Sakir and Kim (2021), while in Advanced Biology textbooks some categories were missing or poorly explained (Tables 3 and 8). This may be because the USS-NCS and its Guidelines do not provide any specific recommendations regarding the selection of biodiversity-related topics for Advanced Biology. In addition, the substantial volumes of other topics may have significantly restricted the number of pages allocated to biodiversity-related topics.

Most upper secondary school students opt for Basic Biology but not for Advanced Biology. For example, in 2023, more than 90% of students took Basic Biology, but only about 20% took Advanced Biology (estimated from the data provided by The Jiji Press, 2024). Therefore, biodiversity and its related concepts should be taught in Basic Biology. Actually, in the current Basic Biology textbooks, topics on most of biodiversity-related categories, which

Sakir and Kim (2021) proposed, were covered (Table 3), and particularly the causes of biodiversity loss were described well.

However, we would like to point out that there were some issues regarding the selection of topics and their arrangement. As for "biodiversity conservation," most Basic Biology textbooks mentioned and explained nature and ecosystem conservation. Perhaps, the editors/authors of the textbooks were following the USS-NCS, which recommend "allowing students to realize the importance of ecosystem conservation (MEXT, 2018, p. 119)." As a result, teachers need to supplement their teaching to students that ecosystem conservation contributes to biodiversity conservation. Most textbooks also mentioned rare and endangered species and their protection. Regarding this, it is desirable to describe measures, not only *in situ* but also *ex situ*, to prevent their extinction, as in Indonesia and the United States biology textbooks (Sakir and Kim, 2021). In addition, some examples of biodiversity conservation at the international level as well as at the local level should be provided.

Regarding the category "biodiversity measurement," most textbooks only explained environmental impact assessment for appropriate land development. Other topics such as "how to measure biodiversity" or "biodiversity assessed by species evenness" should be added. Since topics related to local biodiversity seem to be mentioned only occasionally in textbooks, local biodiversity needs to be taught more comprehensively to set up a section like "Local Biodiversity in Japan." This section includes some representative sites such as coral reefs and mangrove forests in Ryukyu Islands, some countryside forests (Satoyama), and Ramsar Conservation-registered wetlands areas, as well as endangered native species and invasive alien species in Japan. In the current Basic Biology textbooks, the only topic related to the category "biodiversity value" was ecosystem services. Yamamoto (2015) suggested introducing the idea of environmental ethics when teaching topics in the unit "Diversity of Organisms, and Ecosystems." Environmental ethics is required not only for understanding biodiversity values but also for recognizing the necessity of biodiversity conservation.

***Selection of indexed terms and of key terms***

In the USS-NCS (MEXT, 2018) and its Guidelines (MEXT, 2021), it is recommended that "Focusing on important terms, approximately 200 to 250 words, the students should be instructed to understand the concepts related to those terms while using their thinking skills." Following this instruction, the number of key terms included in each *O* edition of Basic Biology textbook published in 2022 ranged from 190 to 249 (Nakamichi *et al.* 2023).

Key terms are considered to be those that are essential for learning important concepts or topics. Also, the terms included in the index are likely to be similar. How do textbook editors/authors decide on key terms? Perhaps they made a concept map for each topic in biology subjects and determined key terms. However, in some textbooks, the importance of some key terms is unclear. For example, in one textbook, ecosystem balance was not treated as a key term, but resilience was. The term resilience is a useful term in understanding a phenomenon, ecosystem balance, since ecosystem balance (ecosystem stability) is maintained by the resilience of an ecosystem. In this case, ecological balance should be considered a higher-level concept of resilience, so ecosystem balance is a more important term. Another example is one textbook that treated genetic resources as a key term, but biodiversity was not a key term. Abundant

genetic resources can be secured by the conservation of biodiversity. We cannot understand why the editors/authors of this textbook considered genetic resources to be more important than biodiversity in biology. A similar problem existed with collecting index terms, but as we have already shown some examples above, we do not mention them here. Editors/authors of biology textbooks should be careful with the selection of terms included in the index and treated as key terms.

For the selection of such key terms, Nakamichi (2020) has proposed establishing a hierarchical classification to evaluate the importance of terms, *i.e.*, higher concepts (highly comprehensive terms) are placed at level 1, middle concepts (lesser comprehensive terms) at level 2, and lower concepts (specific individual terms) at level 3 or 4. By establishing a hierarchy in this way, terms that are considered important (key terms) and that should be collected in the index can be selected. According to this proposal, we set three ranks of categories in the present paper, and classified each term found in the textbooks surveyed into the most appropriate specific individual category (see the table in the Appendix).

***Issues regarding terminology***

During the last decade, in Japan, some recommendations have been made about the terminology to be used in biology education at upper secondary schools and biology textbooks (Matsuura, 2013, Atsumi *et al*., 2018; JBSS-SCJ, 2019; Nakamichi, 2020). Partially in response to these recommendations, the current Guidelines on USS-NCS (MEXT, 2021) indicate the range of the number of terms used in teaching biology. Atsumi *et al*. (2018) also pointed out that the inconsistencies in the spelling of terms should be eliminated, but there are still a large number of such spelling inconsistencies found in biology textbooks.

As mentioned above, the textbooks surveyed contained two different Japanese spellings for biodiversity: a compound word SEIBUTSU-TAYOUSEI and a phrase SEIBUTSU NO TAYOUSEI (In our paper, we distinguished the former as biodiversity from the latter, the diversity of organisms). The current USS-NCS and its Guideline use the latter term consistently, so some textbook editors/authors might have followed suit. In Basic Biology, students learn about the diversity of organisms in Unit 1 and biodiversity in Unit 3. We think the terms should be used differently so that students do not confuse them. We would like to point out that the editors of the USS-NCS and its Guidelines need to be more careful with their terminology. (See Note) Similarly, the diversity of genes, the diversity of species, and the diversity of ecosystems should be distinguished from the terms for three biodiversity levels, genetic diversity, species diversity, and ecosystem diversity, respectively.

On the other hand, there were some terms that we treated as the same even if there was a slight difference in meaning. For example, the result of excessive logging can be expressed as “deforestation,” “forest destruction” or “forest loss.” However, in this case, we treated them the same because the measure that distinguishes between these three, *i.e.* the extent of logging, is not clear and “forest destruction” may cover the other two meanings.

Such variations in notation were found in many places, even in a single textbook, making it difficult to summarize the survey results. From an educational point of view, editors/ authors of biology textbooks should be careful with their terminology to avoid students’ confusion and misunderstanding.

**Note**

In the Japanese translation of the Convention on Biological Diversity (Biodiversity Center of Japan, undated), the translation of biological diversity (biodiversity) is SEIBUTSU NO TAYOUSEI (the diversity of organisms). This is a term that is exclusive to the Convention on Biological Diversity, and since the term has a strict definition in the Convention, *i.e.,* “"Biological diversity" means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems” (CBD Secretariat, 2016). Therefore, no one would misunderstand it as "the existence of organisms having a variety of different characteristics." However, in Basic Biology, students first learn that although organisms have a variety of forms, they have the same basic characteristics. The diversity of organisms in this context does not mean the biodiversity defined by the Convention on Biological Diversity. In biology education, we believe it is necessary to use two different terms, the diversity of organisms and biodiversity, to avoid misunderstandings among students.

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## APPENDIX

***Table: A proposed tentative categorization of biodiversity-related terms found in current Basic Biology textbooks and Advanced Biology textbooks.***

| Superordinate categories | Subordinate categories | Specific individual categories | | Terms |
|---|---|---|---|---|
| Biodiversity | Biodiversity | Biodiversity | | Biological diversity / Biodiversity |
| | | | | Diversity of organisms |
| | Three levels of biodiversity | Gene level | | Genetic diversity |
| | | | | Diversity of genes / gene diversity |
| | | | | Intraspecific diversity / Genetic diversity within a species |
| | | Species level | | Species diversity |
| | | | | Diversity of species |
| | | Ecosystem level | | Ecosystem diversity |
| | | | | Diversity of ecosystems |
| | Factors that maintain and enhance biodiversity | Ecosystem stability | | Ecosystem balance / Ecological balance |
| | | | | Resilience |
| | | Disturbance | | Disturbance |
| | | | | Natural disturbance / Disturbance that occurs naturally |
| | | | | Intermediate disturbance hypothesis (theory) |
| Evaluation of biodiversity (Biodiversity measurement) | Environmental impact assessment | | | Environmental Impact Assessment Law |
| | | | | Environmental impact assessment |
| | Biological evaluation | Native species（Local biodiversity evaluation） | | Native species / Domestic species / Native organisms |
| | | | | Endemic species |
| | | | | Native species / Native vegetation |
| | | | | Rare species / Rare organisms |
| | | | | Endangered species of wild fauna and flora |
| | | Alien species | | Alien species / Alien organisms |
| Causes of biodiversity decline or loss | General factors | | | Artificial disturbance / Anthropogenic disturbance |
| | Extinction | Extinction | | Extinction |
| | | Level and scale of extinction | | Extinction of a population |
| | | | | Extinction of a species |
| | | | | Mass extinction |
| | | Cause and principle of extinction | Isolation of a population and process of extinction | Fragmentation / Habitat fragmentation |
| | | | | Isolation / Isolation of a population |

| | | | | |
|---|---|---|---|---|
| | | | | Local populations |
| | | | | Allee's effect |
| | | | | Inbreeding |
| | | | | Deleterious genes |
| | | | | Inbreeding depression |
| | | | | Extinction vortex |
| | | | | Population viability |
| | | | Settling down of alien species | Importation or intrusion of alien organisms, and their settling down |
| | | | | Invasive alien species / invasive alien organisms |
| | | | | Genetic pollution / genetic disturbance |
| | Other factors (Anthropogenic factors) | Global warming | Greenhouse effect | Greenhouse effect |
| | | | | Greenhouse effect gases |
| | | | Global warming and its results | Global warming |
| | | | | Climate change |
| | | | | Coral breaching |
| | | | | Desertification |
| | | | | Salts accumulation / salinization |
| | | Environmental pollution | Pollution | Pollution / environmental pollution |
| | | | Air | Air pollution |
| | | | | Asid rain |
| | | | Water | Eutrophication |
| | | | | Water pollution |
| | | | | Ocean pollution |
| | | | | Blue green algae / Cyanobacterial bloom |
| | | | | Red tide |
| | | | | Water bloom / algal bloom |
| | | | | Microplastics |
| | | Others | Overdevelopment and overexploitation | Habitat destruction |
| | | | | Vegetation destruction |
| | | | | Logging |
| | | | | Deforestation / forest destruction / forest disappearance |
| | | | | Overgrazing |
| | | | | Slash and burn cultivation / swidden agriculture |
| | | | | Overexploitation / overhunting / overfishing |

| | | | | |
|---|---|---|---|---|
| Biodiversity value | | Ecosystem services | | Ecosystem services |
| | | | | Supporting services |
| | | | | Provisioning services |
| | | | | Regulating services |
| | | | | Cultural services |
| | | Others | | Genetic resources |
| | | | | Natural capital |
| Conservation of biodiversity | | Conservation and protection | | Conservation |
| | | | | Protection |
| | | Others | | Society with sound material cycles |
| | International level | Conventions, resolutions, and protocols | Convention on Biological Diversity | The Convention on Biological Diversity |
| | | | | The Strategic Plan of the Convention on Biological Diversity, Nagoya Protocol |
| | | | | Cartagena Protocol on Biosafety |
| | | | Protection of organisms and their habitat | The Convention on Wetlands of International Importance especially as Waterfowl Habitat |
| | | | | Convention on International Trade in Endangered Species of Wild Fauna and Flora |
| | | | | Sustainable Development |
| | | | | Sustainable Development Goals / SDGs |
| | | | United Nations Framework Convention on Climate Change | Kyoto Protocol (Framework until 2020) |
| | | | | Paris Agreement (Framework from 2020) |
| | | | Organizations | Conference of the Parties to the United Nations Framework Convention on Climate Change |
| | | | | Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services |
| | | | | International Union for Conservation of Nature and Natural Resources |
| | | | | Conservation International |
| | | Conservation targets and conservation activities | Protection areas | Protected areas |
| | | | | Ramsar Convention-designated wetlands / Ramsar sites |
| | | | | Biodiversity hotspots |
| | | | | Hotspots on biodiversity |
| | | | | Hotspots |
| | | | Activities | Ecological footprint |
| | | | | Biodiversity footprint |

| | | | | |
|---|---|---|---|---|
| | | | | Ecotourism |
| | | | | Eco label |
| | | | | Wise Use |
| | | | Systems | Certification Systems |
| | | | | Forest Certification Systems |
| | Domestic level | Invasive Alien Species Act | | Invasive Alien Species Act |
| | | | | Specified invasive alien species |
| | | Conservation of endangered species | | The Law for the Conservation of Endangered Species of Wild Fauna and Flora |
| | | | | Endangered species |
| | | | | Extinct in wild |
| | | | Red list | Red list |
| | | | | Red data book |
| | | Conservation targets and conservation activities | Countryside areas | Countryside areas |
| | | | | Satoyama / countryside forests |
| | | | | Forest of mixed trees |
| | | | Wetlands | Wetlands |
| | | | | Coral reef |
| | | | | Tidal flat |
| | | | | Mangrove / mangrove forests |
| | | | Forests | Forest environment tax |
| | | | | Forest conservation / conservation of forest |
| | | | | Afforestation |
| | | | Others | Water clean-up / water purification |
| | | | | Extermination of invasive alien species |
| | | | | Fish ladder / fishway |
| | | | | Ecological corridor / green corridor |
| | | | | Underpass |
| | | | | Retarding water area / retarding basin |
| Other | | | | Diversity |