Diversity of brittle star and sea urchin (Echinoderm: Ophiuroidea, Echinoidea) of Krakal and Watu Kodok beach, Gunung Kidul, Yogyakarta

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Abstract. Ophiuroidea and Echinoidea are usually lived associated with coral reef and seaweed. Krakal and Watu Kodok Beach of Gunung Kidul Regency have characteristics of karst rocks, rubble and fast-current sea. They have large intertidal zone that allows ophiuroid and echinoid trapped among the basin during low tide. The research was aimed to identify and determine the diversity of Brittle Star and Sea Urchin in Krakal and Watu Kodok Beach. Survey was conducted on November-December 2018 at Krakal and Watu Kodok Beach. The samples were taken using quadrant transect method during low tide. The result of present work showed a total of 391 individuals belonging to Ophiocomidae Ophiurid (2 species) and 279 individuals of 4 species echinoids belong to 2 families (Echinothuriidae and Diadematidae) lived in both beach. The highest abundance of Ophiocoma scolopendrina was found in Krakal beach (33.4 ind.m$^{-2}$) while Echinometra oblonga was biggest in Watu Kodok beach (14.4 ind.m$^{-2}$). In both location the diversity was low with medium to high similarity.

Introduction

Echinoderm are derived from Greek words, i.e. “echino” means thorns and “derma” means skin, so this animal is called a spiny skinned animal. These organisms have a high regeneration rate, with the autotomy ability on parts of the body that are lost or damaged [1]. Comprehensive information on the diversity of Echinodermata in Indonesia has not still limited [2].

One interesting class of echinoderm are Ophiuroidea or Brittle Star. This benthic animal lives in the bottom of the water [3]. Brittle star resemble to starfish in terms of symmetrical pentaradial body shape. Their body form (namely central discs) protected by ossicle and coated with granules and thorns. The majority of brittle star species are dweller under the seabed, buried in mud, or hiding in crevices and pits of rocks or corals. Some species are epizoic, which live in various hosts such as gorgonian or black coral [4] [5]. This organism is a negative phototaxis and tends to hide in its habitat. In marine foodweb Ophiuroidea act as prey of other biota, such as demersal fish, crabs and starfish [6].
Another member class of Echinoderm is Echinoidea which 95% of its body surface is thorns [7]. Sea urchin have a rigid body namely plate or test on which their thorns are attached. Sea urchins are spreaded from the shallow intertidal area to the deep sea, but each species has a specific habitat distribution. They prefer more coral and seagrass ecosystems rather than hard substrates, especially in seagrass beds which have mixture of sand and coral fragments [8]. The existence of sea urchins in benthic waters has an important role, especially in the coral reef ecosystem. The existence of sea urchins in this ecosystem maintaining the balance between coral and algae. This is because sea urchin is herbivorous that feeds on algae found on coral reefs. It causes a decrease in an amount of macroalgae on coral reefs and rebalances the space where the coral reefs can live [9].

Krakal and Watu Kodok Beach are located in Gunung Kidul, Yogyakarta. They have fast flowing waves and karst rocks that form terrain and tear the currents. This beach has a wide tidal zone with small pools which can be used as suitable habitat for juvenile reef fish development and other associated organisms such as ophiuroid and echinoid [10]. The beach is having wide intertidal zone thus allows to observe marine biotas that was trapped in the basins or pools [11]. Previous studies done on Krakal Beach found 3 species of brittle star and 3 species of sea urchin [12] [13], i.e. Ophiocoma erinaceus, O. riisei, O. scolopendrina, Echinometra mathaei, E. oblonga, and E. viridis., but none has been studied at Watu Kodok Beach. The research was aimed to identify and compare the diversity of Brittle Star and Sea Urchin in Krakal and Watu Kodok Beach.

2. Research Methods

Sampling sites
We observed brittle star (Ophiuroidea) and sea urchin (Echinoidea) found in Krakal and Watu Kodok Beach. Observation used quadrant transect method [14] and carried out during low tide. In each beach, five lines were set up with 25 meters interval (Figure 1).

![Research Map Location of Krakal and Watu Kodok Beach, Gunungkidul, Yogyakarta](Source: Indonesian Earth Map Scale 1:25,000, BIG Publication, 2015 and Google earth Satellite Image 2019)
At each line was drawn from the lowest recede point towards the sea along 110 meters using a roll meter. In each line, there are ten of 1 m x 1 m quadrat transect plots with 10 meters interval. The ophiuroid and echinoid found in the transect were observed, identified and counted. The identification is done by observing the morphology of the sample such as the shape and color of the arms according to [15] [16].

Data analysis

Individual abundance is the number of individuals per unit area. The abundance of each species in each line was calculated following [17]. Community structure is a concept that studies the composition of species and their abundance in a community [18]. The diversity and similarity index of brittle stars and sea urchins was calculated using the Shanon-Wiener formula [3]. Calculation of dominance index using the Simpson formula [17].

3. Results and Discussion

The composition of brittle star and sea urchins

This study found two species of brittle stars family of Ophicomidae in the observation locations, i.e. *Ophiocoma erinaceus* and *O. scolopendrina*, and four species of sea urchins belong to family of Camarodonta, i.e. *Echinometra oblonga*, *E. mathaei*, *E. vanbruntii*, and one species of Diadematoida, i.e. *Diadema setosum* (Figure 2; Table 1). The characteristics of the Ophicomidae family is unbranched arms that distinguish it from the Euryalidae family. The central disk has a darker color compared to its arms and five symmetrical and unbranched arms. Species from the Camarodonta order have thicker thorns, shorter, and tend to be blunt on the edges, whereas the species of the order Diadematoida has thin thorns but long and pointed edges.

![Ophiocoma scolopendrina](image1.png)  ![Ophiocoma erinaceus](image2.png)  ![Echinometra oblonga](image3.png)

![Echinometra vanbruntii](image4.png)  ![Echinometra mathaei](image5.png)  ![Diadema setosum](image6.png)

*Figure 2. Species of Brittle Stars and Sea Urchins found in Krakal and Watu Kodok Beach, Yogyakarta.*
Table 1. The Species composition of Brittle Stars and Sea Urchins in each Line found in Krakal and Watu Kodok Beach, Yogyakarta

| Class/Species          | Krakal Beach | Watu Kodok Beach |
|------------------------|--------------|------------------|
|                        | L1 | L2 | L3 | L4 | L5 | L1 | L2 | L3 | L4 | L5 |
| Ophiuroidea            |    |    |    |    |    |    |    |    |    |    |
| O. scoopendrina        | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| O. erinaceus           | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| Echinoidea             |    |    |    |    |    |    |    |    |    |    |
| Ordo: Camarodonta      |    |    |    |    |    |    |    |    |    |    |
| E. oblonga             | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| E. vanbruntii          | +  | +  | +  | +  | +  | -  | +  | -  | -  | -  |
| E. mathaei             | -  | -  | +  | -  | -  | -  | +  | -  | -  | +  |
| Ordo: Diadematoidea    |    |    |    |    |    |    |    |    |    |    |
| D. setosum             | +  | +  | +  | +  | -  | -  | -  | -  | -  | -  |

Number of species

4 4 6 4 4 3 3 3 3

Note: L: Line, +: found, -: not found

*O. scoopendrina* was found in seagrass habitats or among reefs covered by seaweed in almost all sampling points, both on Krakal and Watu Kodok Beach. Species of the Ophiuroidea class are generally found in the Seagrass area and in inter-reef basins. According to [1], Echinoderms occupy all habitats in coral reef or free living in offshore waters. In the coral reef ecosystem, they live in varieties habitats such as live coral, dead coral, coral fragments, and seagrass areas. They are negative phototaxis animals and tends to hide during the day. [7] also found *D. setosum* on Sundak Beach in sandy areas, seagrass beds, reefs and coastlines, to rocky areas. *E. oblonga* were the dominant sea urchins on Krakal and Watu Kodok Beach.

*O. scoopendrina* found as highest abundance on Krakal Beach (33.4 ind.m⁻²) while in Watukodok Beach *E. oblonga* was the highest abundant (14.4 ind.m⁻²) (figure 3). The difference in the abundance of brittle stars and sea urchins on Krakal Beach and Watu Kodok Beach is thought caused by differences in water quality and food availability. [19] stated that environmental conditions such as temperature, salinity, pH, flow velocity, and substrate affect the abundance of organisms. The food availability and competition for food among individuals also influence the abundance of organisms [20].

Figure 3. Abundance (Individu.m⁻²) of Brittle Star and Sea Urchin in Krakal (A) and Watu Kodok (B) beach, Yogyakarta
Diversity ($H'$), Similarity ($e$), and Dominance ($C$) Brittle Stars and Sea urchins

The results of the research revealed that the diversity index of brittle stars and sea urchins on Krakal and Watu Kodok Beach were categorized as low (table 2). This was due to the small number of species found, i.e. only six species of two classes. Low diversity due to several factors such as the number of species or number of individuals obtained [21], the presence of several species found in abundance, homogeneity of the substrate and the condition of two important coastal ecosystems (seagrass beds and coral reefs) as a habitat for echinoderm. The value of diversity is not only could be seen from the number of species but also from the distribution of individuals in each species and depends on the abundance of individuals within the species [22]. The similarity index of brittle stars and sea urchins on Krakal Beach was medium category, while on Watu Kodok Beach was classified into the high category (table 2). The smaller similarity of species in a community means the distribution of the number of individuals of each species is not the same, there is a tendency that the community is dominated by a particular species [23]. This could be seen from the number of certain species more than species. As in Krakal, it is dominated by O. scolopendrina while in Watu Kodok it is dominated by E. oblonga.

Table 2. The Community Structures of Brittle Stars and Sea Urchins on Krakal and Watu Kodok Beach

| Location/Line | Diversity Index ($H'$) | Category | Similarity Index ($e$) | Category | Dominance Index ($D$) | Category |
|---------------|------------------------|----------|-----------------------|----------|----------------------|----------|
|               |                        |          |                       |          |                      |          |
| Krakal Beach  |                        |          |                       |          |                      |          |
| Line 1        | 1.132                  | Medium   | 0.817                 | High     | 0.363                | No dominance |
| Line 2        | 0.875                  | Low      | 0.488                 | Medium   | 0.511                | Dominance |
| Line 3        | 0.348                  | Low      | 0.251                 | Low      | 0.852                | Dominance |
| Line 4        | 0.634                  | Low      | 0.457                 | Medium   | 0.653                | Dominance |
| Line 5        | 0.928                  | Low      | 0.699                 | Low      | 0.449                | Dominance |
| Watu Kodok Beach |                      |          |                       |          |                      |          |
| Line 1        | 0.828                  | Low      | 0.75                  | High     | 0.514                | Dominance |
| Line 2        | 0.325                  | Low      | 0.469                 | Medium   | 0.82                 | Dominance |
| Line 3        | 0.941                  | Low      | 0.679                 | High     | 0.444                | No dominance |
| Line 4        | 0.681                  | Low      | 0.62                  | High     | 0.585                | Dominance |
| Line 5        | 0.793                  | Low      | 0.721                 | High     | 0.506                | Dominance |

Water quality

Water quality parameters were measured during the sample observation, such as temperature, salinity, and pH (table 3). According to [24] the temperature range that supports the life of Echinoderms is between 28–44°C. Sea urchins do not have special adaptations to temperature increases in accordance with the maximum limit of 36-40°C, and temperatures below the minimum threshold [9]. Brittle stars from the Ophiocomidae family have a maximum lethal temperature limit of 37.5 to 40.5°C. While the minimum threshold is around 10°C, a decrease temperature below 10°C causes this biota to die within 7 hours to 16 hours.

Table 3. Water Quality Parameters on Krakal and Watu Kodok Beach, Gunungkidul, Yogyakarta

| Location            | Temperature (°C) | Salinity (ppt) | pH  |
|---------------------|------------------|----------------|-----|
| Krakal Beach        | 31.43            | 34             | 6.8 |
| Watu Kodok Beach    | 34.33            | 31.8           | 7   |
| Reference            | 28–34 (Aziz) [24] | 30–34 (Aziz) [25] | 7–8 (Aziz) [24]   |
4. Conclusions

Overall his study found two species of brittle stars family of Ophiocomidae in the observation locations, i.e. *Ophiocoma erinacea* and *O. scolopendrina*, and four species of sea urchins belong to family of amarodonta, i.e. *Echinometra oblonga*, *E. mathaei*, *E. vanbruntii*, and one species of Diadematoidea, i.e. *Diadema setosum*. There are higher number species Brittle stars and sea urchin found in Krakal Beach than in Watu Kodok Beach, with the diversity was low to medium, showed that the habitat more available. There is dominance species in both locations, i.e. *O. scolopendrina* in Krakal Beach and *E. oblonga* in Watu Kodok Beach revealed difference habitat condition in both locations.

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Spin dynamics in geometrically frustrated antiferromagnetic pyrochlores

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Captions should be below the figure and separated from it by a distance of 6 points—although to save space it is acceptable to put the caption next to the figure. Figures should be numbered sequentially through the text—‘Figure 1’, ‘Figure 2’ and so forth and should be referenced in the text as ‘figure 1’, ‘figure 2’, ... and not ‘fig. 1’, ‘fig. 2’, ....
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1.11.1. Examples. The following examples show how to format a number of different figure/caption combinations. Note that the table borders are shown as broken lines for guidance only.

**Figure 3.** Figure with short caption (caption centred).

**Figure 4.** This is a figure with a caption that is wider than the actual graphic. To save space you can put the caption to the right of the figure by placing the graphic and justified caption in a table with one row and two columns.

**Figure 5.** In this case simply justify the caption so that it is as the same width as the graphic.

**Figure 6.** These two figures

**Figure 7.** These two figures
have been placed side-by-side to save space. Justify the caption.

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Tables
Note that as a general principle, for large tables font sizes can be reduced to make the table fit on a page or fit to the width of the text.

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Tables should be centred unless they occupy the full width of the text.

1.14. Tables in parts
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1.16. Rules in tables
Tables should have only horizontal rules and no vertical ones. Generally, only three rules should be used: one at the top of the table, one at the bottom, and one to separate the entries from the column headings. Table rules should be 0.5 points wide.

1.17. Examples
Because tables can take many forms, it is difficult to provide detailed guidelines; however, the following examples demonstrate our preferred styles.

Table 3. A simple table. Place the caption above the table. Here the caption is wider than the table so we extend it slightly outside the width of the table. Justify the text. Leave 6 pt of space between the caption and the top of the table.

| Distance (m) | Velocity (ms$^{-1}$) |
|-------------|----------------------|
| 100         | 23.56                |
| 150         | 34.64                |
| 200         | 23.76                |
| 250         | 27.9                 |

1.17.1. More complex tables. The following is a slightly more complex table with a caption that is narrower than the table. Centre the caption across the width of the table. If it is difficult to make a table fit the page, use a smaller font. Headings should normally be in Roman (i.e., not bold or italic)
type, have an initial capital and normally align left (but centred sometimes looks better); it is up to the author to choose a layout that is most useful to the reader. Columns of numbers normally align on the decimal point.

Table 4. A slightly more complex table with a narrow caption.

|       | Wake Chi Sqr. \((N=15, df=1)\) | \(p\) | Stage 1 Chi Sqr. \((N=15, df=1)\) | \(p\) | Stage 2 Chi Sqr. \((N=15, df=1)\) | \(p\) |
|-------|---------------------------------|------|---------------------------------|------|---------------------------------|------|
| \(F_3\) | 1.143                           | 0.285| 0.286                           | 0.593| 0.286                           | 0.593|
| \(F_z\) | 1.143                           | 0.285| 0.067                           | 0.796| 0.067                           | 0.796|
| \(C_4\) | 2.571                           | 0.109| 0.600                           | 0.439| 1.667                           | 0.197|

Table 5. A slightly more complex table with a caption that is the same width as the table. Simply place the caption inside a row at the top of the table and merge (combine) the cells together so that you have a single table cell the width of the table. Justify the caption.

|       | Wake Chi Sqr. \((N=15, df=1)\) | \(p\) | Stage 1 Chi Sqr. \((N=15, df=1)\) | \(p\) | Stage 2 Chi Sqr. \((N=15, df=1)\) | \(p\) |
|-------|---------------------------------|------|---------------------------------|------|---------------------------------|------|
| \(F_3\) | 1.143                           | 0.285| 0.286                           | 0.593| 0.286                           | 0.593|
| \(F_z\) | 1.143                           | 0.285| 0.067                           | 0.796| 0.067                           | 0.796|
| \(C_z\) | 1.143                           | 0.285| 0.077                           | 0.782| 0.286                           | 0.593|

1.18. Notes to tables

If you wish to format a table so that it contains notes (table footnotes) to the entries within the body of the table and/or within the table caption, these notes should be formatted using alphabetic superscripts such as \(^a\), \(^b\), \(^c\) and so forth. Notes within the table caption should be listed first. Notes should be placed at the bottom of the table; one convenient method is to create an empty row at the bottom of the table to contain them. Again, merge the cells to give you a single cell the width of the table. Table notes should be 10 point Times Roman. Each note should be on a separate line.

Table 6. A table with headings spanning two columns and containing notes\(^a\).

| Nucleus | Thickness \((\text{mg cm}^{-2})\) | Composition | Separation energies \(\square, \text{n} \,(\text{MeV})\) | \(\square, 2\text{n} \,(\text{MeV})\) |
|---------|---------------------------------|-------------|---------------------------------|------|
| \(^{181}\text{Ta}\) | 19.3±0.1\(^b\) | Natural | 7.6 | 14.2 |
| \(^{208}\text{Pb}\) | 3.8±0.8\(^c\) | 99% enriched | 7.4 | 14.1 |
| \(^{209}\text{Bi}\) | 2.6±0.01\(^c\) | Natural | 7.5 | 14.4 |

\(^a\) Notes are referenced using alpha superscripts.

\(^b\) Self-supporting.

\(^c\) Deposited over Al backing.

Equations and mathematics

1.19. Fonts in Equation Editor (or MathType)

Make sure that your Equation Editor or MathType fonts, including sizes, are set up to match the text of your document.

1.20. Points of style

1.20.1. Vectors. Bold italic characters is our preferred style but the author may use any standard notation; for example, any of these styles for vectors is acceptable:
‘the vector cross product of \(a\) and \(b\) is given by \(a \times b\)’, or
‘the vector cross product of \(a\) and \(b\) is given by \(a \times b\)’, or
‘the vector cross product of \(\vec{a}\) and \(\vec{b}\) is given by \(\vec{a} \times \vec{b}\)’.

1.20.2. The solidus (‘/’). A two-line solidus should be avoided where possible; for example, use
\[\frac{1}{M_o} \left(\int_0^\infty d\omega \frac{|S_0|^2}{N}\right)^{-1}\]
instead of
\[\frac{1}{M_o} \int_0^\infty d\omega \frac{|S_0|^2}{N}\]
\[\left(\frac{x^2 + y^2}{x + y}\right)^{1/2}\]
instead of \(\sqrt{x^2 + y^2}\).

1.20.3. Roman and italic in mathematics. Variables should be in italic; however there are some cases where it is better to use a Roman font:
- Use a Roman \(d\) for a differential \(d\), for example, \(\tan \theta = \frac{dy}{dx}\).
- Use a Roman \(e\) for an exponential \(e\); for example, \(y = e^x\).
- Use a Roman \(i\) for the square root of \(-1\); e.g., \(i = \sqrt{-1}\).
- Certain other common mathematical functions, such as \(\cos\), \(\sin\), \(\det\) and \(\ker\), should appear in Roman type.
- Subscripts and superscripts should be in Roman type if they are labels rather than variables or characters that take values. For example in the equation
\[\epsilon_m = -g\mu_B m\]
\(m\), the \(z\) component of the nuclear spin, is italic because it can have different values whereas \(n\) is Roman because it is a label meaning nuclear.

1.21. Alignment of mathematics
The preferred style for displayed mathematics in Journal of Physics: Conference Series is to centre equations; however, long equations that will not fit on one line, or need to be continued on subsequent lines, should start flush left. Any continuation lines in such equations should be indented by 25 mm.
Equations should be split at mathematically sound points, often immediately before =, + or – signs or between terms multiplied together. The connecting signs are not repeated and appear only at the beginning of the turned-over line. A multiplication sign should be added to the start of turned-over lines where the break is between two multiplied terms.

1.21.1. Small displayed equations: Some examples:
\[\phi_a(r) = (2\pi)^{3/2} \exp\left(i \mathbf{k} \cdot \mathbf{r}\right)\]  
\[A^{(3/2)} = A^{(+) + A^{(-)}} \quad (I = \frac{3}{2})\]  
However, if equations will fit on one line, do so; for example, (5) may also be formatted as:
\[C(12) = \left[\mathbf{\hat{r}}(x) \cdot \mathbf{\hat{r}}(x + r)\right] \approx 1 - \text{const} \int_0^r \frac{x^2}{x^2 + \cdots} \approx 1 - \text{const} \int_0^r \frac{d^3r}{r^3} \ln \left(\frac{L}{r}\right) + \cdots\]  

1.21.2. Large display equations: examples. If an equation is almost the width of a line, place it flush left against the margin to allow room for the equation number.
Miscellaneous points

- Exponential expressions, especially those containing subscripts or superscripts, are clearer if the notation \( \exp(\ldots) \) is used, except for simple examples. For instance, \( \exp[i k x t] \) and \( \exp(z^2) \) are preferred to \( e^{i k x t} \) and \( e^{z^2} \), but \( e^2 \) is acceptable. Similarly the square root sign \( \sqrt{\ldots} \) should only be used with relatively simple expressions, e.g. \( \sqrt{2} \) and \( \sqrt{a^2 + b^2} \), but in other cases the power \( 1/2 \) should be used.

- It is important to distinguish between \( \ln = \log_e \) and \( \lg = \log_{10} \).

- Braces, brackets and parentheses should be used in the following order: \{[()]\}. The same ordering of brackets should be used within each size. However, this ordering can be ignored if the brackets have a special meaning (e.g. if they denote an average or a function).

- Decimal fractions should always be preceded by a zero: for example 0.123 not .123 (note, do not use commas, use the decimal point).

- Equations that are referred to in the text should be numbered with the number on the right-hand side.

Equation numbering

Equations may be numbered sequentially throughout the text (i.e., (1), (2), (3),...) or numbered by section (i.e., (1.1), (1.2), (2.1),...) depending on the author’s personal preference. In articles with several appendices equation numbering by section is useful in the appendices even when sequential numbering has been used throughout the main body of the text: for example, A.1, A.2 and so forth. When referring to an equation in the text, always put the equation number in brackets—e.g. ‘as in equation (2)’ or ‘as in equation (2.1)’—and always spell out the word ‘equation’ in full, e.g. ‘if equation (5) is factorized’; do not use abbreviations such as ‘eqn.’ or ‘eq.’.

Appendices

Technical detail that it is necessary to include, but that interrupts the flow of the article, may be consigned to an appendix. Any appendices should be included at the end of the main text of the paper, after the acknowledgments section (if any) but before the reference list. If there are two or more appendices they should be called appendix A, appendix B, etc. Numbered equations should be in the form (A.1), (A.2), etc, figures should appear as figure A1, figure B1, etc and tables as table A1, table B1, etc.

References

As part of the production system for Journal of Physics: Conference Series, online versions of all reference lists will, wherever possible, be linked electronically using CrossRef. It is vitally important for all the references to be accurate and to be carefully formatted using the guidelines below, otherwise delays may be incurred and the references may not link through CrossRef.

A complete reference should provide the reader with enough information to locate the article concerned, whether published in print or electronic form, and should, depending on the type of reference, consist of:

- name(s) and initials;
- date published;
- title of journal, book or other publication;
- titles of journal articles may also be included (optional);
- volume number;
• editors, if any;
• town of publication and publisher in parentheses for books;
• the page numbers.

For *Journal of Physics: Conference Series*, please use the Vancouver numerical system where references are numbered sequentially throughout the text. The numbers occur within square brackets, like this [2], and one number can be used to designate several references. The reference list gives the references in numerical, not alphabetical, order.

**Points to note**

- There should be a 5 mm gap between the reference number (e.g., ‘[8]’) and the start of the reference text. Second and subsequent lines of individual references should be indented by 5 mm. For example:

  [1] Aderhold J, Davydov V Yu, Fedler F, Klausing H, Mistele D, Rotter T, Semchinova O, Stemmer J and Graul J 2001 *J. Cryst. Growth* 222 701

- the authors should be in the form surname (with only the first letter capitalized) followed by the initials with no periods between them. Authors should be separated by a comma except for the last two which should be separated by ‘and’ with no comma preceding it.
- The article title (if given) should be in lower case letters, except for an initial capital, and should follow the date.
- The journal title is in italic and is abbreviated. If a journal has several parts denoted by different letters the part letter should be inserted after the journal in Roman type, e.g. *Phys. Rev. A*. Please do not join the part letter to the volume number in bold type.
- Both the initial and final page numbers should be given where possible. The final page number should be in the shortest possible form and separated from the initial page number by an en rule ‘—’, e.g. 1203–14, i.e. the numbers ‘12’ are not repeated.
- References to printed journal articles. A normal reference to a journal article contains three changes of font (see table 6).

**Table 6.** Font styles for a reference to a journal article.

| Element               | Style     |
|-----------------------|-----------|
| Authors, date         | Roman type|
| Article title (optional) | Roman type|
| Journal title         | Italic type|
| Volume number         | Bold type  |
| Page numbers          | Roman type |

Here are some examples taken from published papers:

[1] Strite S and Morkoc H 1992 *J. Vac. Sci. Technol. B* 10 1237
[2] Nakamura S, Senoh M, Nagahama S, Iwase N, Yamada T, Matsushita T, Kiyoku H and Sugimoto Y 1996 *Japan. J. Appl. Phys.* 35 L74

1.23.1. References to preprints. For preprints there are two distinct cases:
1. Where the article has been published in a journal and the preprint is supplementary reference information. In this case it should be presented as:

[1] Kunze K 2003 T-duality and Penrose limits of spatially homogeneous and inhomogeneous cosmologies Phys. Rev. D 68 063517 (Preprint gr-qc/0303038)

2. Where the only reference available is the preprint. In this case it should be presented as

[1] Milson R, Coley A, Pravda V and Pravdova A 2004 Alignment and algebraically special tensors Preprint gr-qc/0401010

1.23.2. References to electronic-only journals. In general article numbers are given, and no page ranges, as most electronic-only journals start each article on page 1.

- For SISSA journals the volume is divided into monthly issues and these form part of the article number

[1] Horowitz G T and Maldacena J 2004 The black hole final state J. High Energy Phys. JHEP02(2004)008

1.23.3. References to books, conference proceedings and reports. References to books, proceedings and reports are similar to journal references, but have only two changes of font (see table 7).

Table 7. Font styles for references to books, conference proceedings and reports.

| Element                                | Style     |
|----------------------------------------|-----------|
| Authors, Date                          | Roman type|
| Book title                             | Italic type|
| Editors                                | Roman type|
| Place (city, town etc) of publication, | Roman type|
| publisher                              |           |
| Volume, page number                    | Roman type|

Points to note

- Book titles are in italic and should be spelt out in full with initial capital letters for all except minor words. Words such as Proceedings, Symposium, International, Conference, Second, etc should be abbreviated to Proc., Symp., Int., Conf., 2nd, respectively, but the rest of the title should be given in full, followed by the date of the conference and the town or city where the conference was held. For Laboratory Reports the Laboratory should be spelt out wherever possible, e.g. Argonne National Laboratory Report.

- The volume number, for example vol 2, should be followed by the editors, in a form such as ‘ed A J Smith and P R Jones’. Use et al if there are more than two editors. Next comes the town of publication and publisher, within brackets and separated by a colon, and finally the page numbers preceded by p if only one number is given or pp if both the initial and final numbers are given.

Examples taken from published papers:

[1] Sze S M 1969 Physics of Semiconductor Devices (New York: Wiley–Interscience)
[2] Dorman L I 1975 Variations of Galactic Cosmic Rays (Moscow: Moscow State University Press) p 103
[3] Caplar R and Kulisic P 1973 Proc. Int. Conf. on Nuclear Physics (Munich) vol 1 (Amsterdam: North-Holland/American Elsevier) p 517
[4] Szytula A and Leciejewicz J 1989 Handbook on the Physics and Chemistry of Rare Earths vol 12, ed K A Gschneidner Jr and L Erwin (Amsterdam: Elsevier) p 133
[5] Kuhn T 1998 Density matrix theory of coherent ultrafast dynamics Theory of Transport Properties of Semiconductor Nanostructures (Electronic Materials vol 4) ed E Schöll (London: Chapman and Hall) chapter 6 pp 173–214

1.24. Reference lists
Up to ten authors may be given in a particular reference; where there are more than ten only the first should be given followed by et al. Abbreviations of the names of periodicals used by IOP Publishing are usually the same as those given in British Standard BS 4148: 1985. If an author is unsure of an abbreviation it is best to leave the title in full. The terms loc. cit. and ibid should not be used. Unpublished conferences and reports should generally not be included in the reference list and articles in the course of publication should be entered only if the journal of publication is known. A thesis submitted for a higher degree may be included in the reference list if it has not been superseded by a published paper and is available through a library; sufficient information should be given for it to be traced readily.

Acknowledgments
Authors wishing to acknowledge assistance or encouragement from colleagues, special work by technical staff or financial support from organizations should do so in an unnumbered Acknowledgments section immediately following the last numbered section of the paper.