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The Effect of Light and Salinity on the Abundance and Biomass of *Skeletonema* Sp. Microalgae

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A B S T R A C T

Microalgae is one type of material that has great potential for human life, because it can grow in a relatively short time and can be developed in a limited area, and several types of microalgae have a high protein content, namely *Skeletonema* sp. *Skeletonema* sp. microalgae is a type of microalgae that has a wide geographical range, both in temperate and tropical waters. One of the most influential environmental parameters in the growth of *Skeletonema* sp. is light and salinity. This is because the light is needed by microalgae in the process of photosynthesis while optimal salinity will affect the osmotic pressure between the protoplasm of organic cells and their environment. The purpose of this study was to determine the effect of the best light and salinity treatment on cell density and biomass of the *Skeletonema* sp. microalgae. This research was conducted at the Aquatic Biology Laboratory, Faculty of Fisheries and Maritime Affairs, University of Riau in August 2022. This research used the experimental method of Completely Randomized Design (CRD), with Completely Randomized Factorial Design, using 2 treatments, namely Light (P1) coming from LED lights with different doses, CR (3600 lux), CS (5400 lux), and CT (7200 lux) and Salinity (P2) originating from Dumai Sea waters with different doses, SR (26 ppt), SS (28 ppt) and ST (30 ppt). Based on the analytical results of the density of variance of *Skeletonema* sp. shows that there is a very real effect (α 0.01). *Skeletonema* sp. cell density. the highest was in the treatment of moderate salinity (SS) 28 ppt with an average cell of 1,045.000 cells/ml and high light (CT) 7200 lux with an average cell of 1,418.000 cells/ml while the lowest abundance was in the second hour -0 lies in the administration of low light (CR) 3600 lux with an average cell of 87.000 cells/ml and high salinity (ST) of 30 ppt with an average cell of 99.000 cells/ml. There is an increase in the abundance of *Skeletonema* sp. caused by the optimal salinity given and also the high light rays that cause continuous cell division.

Keywords: *Skeletonema* sp./ Light, Salinity, Abundance, Biomass

1. Introduction

Skeletonema sp. microalgae is a type of microalgae that has a wide geographical range, both in temperate and tropical waters (Johnson & Wen, 2009; Kim et al., 2014). Habitat of *Skeletonema* sp. namely living in seawater that has a light intensity of less than 500-12000 lux (Winder et al., 2012; Zimmerman, 2006). If the light intensity is less than 500 lux, *Skeletonema* sp. cannot grow, while the growth and development range of salinity is 25-29 ppt and the temperature for growth is 20-34°C (Dennison, 1987; Moore & Wetzel, 2000; Zhang et al., 2011). *Skeletonema* sp. microalgae contain 51.77% protein, 20.02% fat, 5.20% ash, and 16.58% carbohydrates (Aldana-Aranda & Patiño-Suárez, 1998; Doan et al., 2011; St. John & Lund, 1996; Sutomo, 2013). With a high protein content, these microalgae have the potential as a source of food, a source of vitamins, and food supplements for human life. The Microalgae maintenance technique is a technique for growing microalgae (Brooks et al., 2010) in a controlled environment (Chowdhury et al., 2010). Microalgae rearing aims to provide a single species in the culture such as microalgae for the harvesting stage (Abrams et al., 2001). The development of microalgae maintenance techniques is carried out starting from the laboratory scale using microalgae harvesting and aeration techniques.

Microalgae maintenance techniques on a laboratory scale usually require controlled environmental conditions (Takara et al., 2011). The growth of microalgae is closely related to the availability of macro and micronutrients and is influenced by environmental conditions (Hart & Reynolds, 2002). Environmental factors that affect the growth of microalgae include light, nutrients, temperature, pH, and salinity (Duarte et al., 2017)(Abrams et al., 2001; Burton et al., 2012; D'Archino & Piazzi, 2021; Weng et al., 2008; Zlinszky et al., 2014). The most important factor in the life of microalgae, the growth of microalgae cells is influenced by high and low light intensity (Kiran et al., 2016; Xin, Hong-ying, Ke, & Jia, 2010).

Growth of *Skeletonema* sp. highly dependent on irradiation and the wavelength of light that hits plant cells during photosynthesis (Head of the Agricultural Research and Development Agency, 2013; Peng et al., 2016; "Antibacterial Potential of Marine Diatom *Skeletonema* Costatum Against Vibrio Sp Bacteria," 2006). Usually, in a microalgae culture room, the light intensity ranges from 500-5000 lux (Abrams et al., 2001; Cunningham, 1992; D'Archino & Piazzi, 2021; Le et al., 2010; Weng et al., 2008). For the seed supply culture, the light intensity given ranged from 500-1000 lux. For mass culture in an open space, the light intensity is better given below 10,000 lux. Salinity is a very influential environmental factor for the growth of *Skeletonema* sp. Media salinity is related to the ability of microalgae to maintain osmotic pressure between the protoplasm of organic cells and their environment. Salinity

is one of the environmental factors that affect the osmotic pressure between organic cell protoplasm and its environment. Fluctuating salt levels in water can cause obstacles to maintaining microalgae. *Skeletonema* sp. microalgae grow optimally at a salinity of 25-29 ppt.

2. Material and Method

The method used in this study is the experimental method, using a Completely Randomized Design (CRD). This study used 2 factors (light and salinity) with 3 repetitions (daily). Dosing for each treatment is a single treatment on light (P1) which consists of 3 different doses namely low light (CR) 3600 lux, medium light (CS) 5400 lux and high light (CT) 7200 lux, and a single treatment on salinity (P2) namely low salinity (SR) 26 ppt, medium salinity (SS) 28 ppt and high salinity (ST) 30 ppt In preparation for research experiments, the experimental units to be used will be carried out separately with the same number of experimental units to calculate abundance and biomass. In the experiment to calculate abundance and biomass, 3 experimental units will be used for each light and salinity treatment, so there are a total of 12 experimental units. Then to calculate of the abundance of microalgae will be carried out every 6 hours for 1 day while the biomass calculation will be carried out at the 18th hour. The abundance of *Skeletonema* sp. for natural feed culture using the formula below:

$N = A1+A2+A3+A4/4 \times 10^4$

Information:

N : The number of microalgae cells counted (cells/ml)

A1-A4 : Number of microalgae cells in boxes 1 to 4

4 : The number of boxes in the observation *Skeletonema* sp.

10^4 : Volume density of square cells

Data from abundance calculation results are described in graphical form to see the abundance of *Skeletonema* sp. Microalgae, for 1 day. So on, the data for the results of calculating biomass to see changes in organic content. Then tabulated the data obtained, and analyzed using statistics using the ANOVA (Analysis of Variance) test to see differences in the effect of light and salinity treatments on abundance and biomass. If the light and salinity treatments have a significant effect, Duncan's further test will be carried out.

3. Result and Discussion

In research on the growth of *Skeletonema* sp. by giving light and salinity treatment to produce the data presented in Tables 1 and 2.

Table 1. Growth data of Skeletonema sp. In light treatment

P1	Repitation	Time (hours)					Number	Average
		0	6	12	18	24		
CR	1	$43x10^3$	$268x10^3$	$500x10^3$	$896x10^3$	$548x10^3$	**$2.255x10^3$**	**$451x10^3$**
	2	$108x10^3$	$246x10^3$	$486x10^3$	$866x10^3$	$544x10^3$	**$2.250x10^3$**	**$450x10^3$**
	3	$110x10^3$	$256x10^3$	$488x10^3$	$886x10^3$	$568x10^3$	**$2.308x10^3$**	**$461.6x10^3$**
	Total	**$261x10^3$**	**$770x10^3$**	**$1.474x10^3$**	**$2.648x10^3$**	**$1.660x10^3$**	**$6.813x10^3$**	**$1.362x10^3$**
	Average	**$87x10^3$**	**$256.7x10^3$**	**$491.3x10^3$**	**$882.7x10^3$**	**$553.3x10^3$**	**$2.271x10^3$**	**$454.2x10^3$**
CS	1	$38x10^3$	$324x10^3$	$680x10^3$	$1.008x10^3$	$624x10^3$	**$2.674x10^3$**	**$534.8x10^3$**
	2	$126x10^3$	$330x10^3$	$696x10^3$	$1.098x10^3$	$686x10^3$	**$2.936x10^3$**	**$587.2x10^3$**
	3	$132x10^3$	$336x10^3$	$702x10^3$	$1.124x10^3$	$667x10^3$	**$2.961x10^3$**	**$592.2x10^3$**
	Total	**$296x10^3$**	**$990x10^3$**	**$2.078x10^3$**	**$3.230x10^3$**	**$1.977x10^3$**	**$8.571x10^3$**	**$1714.2x10^3$**
	Average	**$98.7x10^3$**	**$330x10^3$**	**$692.7x10^3$**	**$1.076x10^3$**	**$659x10^3$**	**$2.857x10^3$**	**$571.4x10^3$**
CT	1	$46x10^3$	$386x10^3$	$806x10^3$	$1.420x10^3$	$702x10^3$	**$3.360x10^3$**	**$672x10^3$**
	2	$136x10^3$	$366x10^3$	$814x10^3$	$1.368x10^3$	$728x10^3$	**$3.412x10^3$**	**$682.4x10^3$**
	3	$142x10^3$	$388x10^3$	$843x10^3$	$1.466x10^3$	$702x10^3$	**$3.541x10^3$**	**$708.2x10^3$**
	Total	**$324x10^3$**	**$1.140x10^3$**	**$2.463x10^3$**	**$4.254x10^3$**	**$2.132 x10^3$**	**$10.313x10^3$**	**$2.062x10^3$**
	Average	**$108x10^3$**	**$380x10^3$**	**$821x10^3$**	**$1.418x10^3$**	**$710.7x10^3$**	**$3.437x10^3$**	**$6.875x10^3$**

Information:

P1 : Light treatment

CR : Light intensity of 3600 lux

CS : Light intensity of 5400 lux

CT : Light intensity of 7200 lux

Based on the results of observations of the abundance of *Skeletonema* sp. based on the administration of different light treatments the highest was at the 18th hour which was located in the high light treatment (CT) 7200 lux with an average cell of 1,418.000 cells/ml while the lowest abundance was at the 0th hour located in the low light treatment (CR) 3600 lux with an average cell of 87.000 cells/ml (Table 1). There is an increase in the abundance of *Skeletonema* sp. This is due to the optimal salinity given at 28 ppt and also light rays which cause continuous cell division (Figure 1).

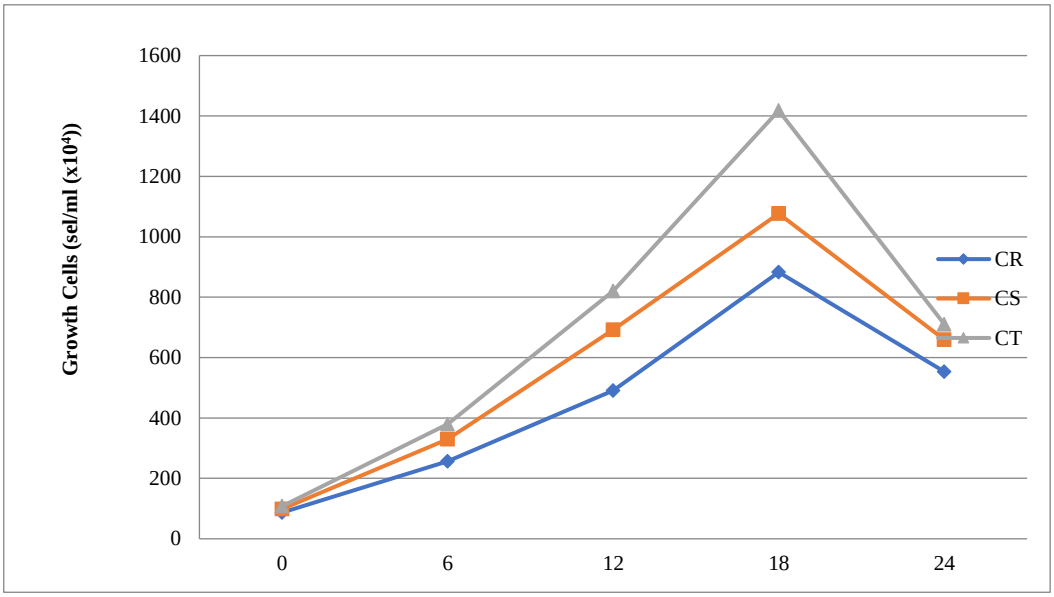

Figure 1. *Skeletonema* sp. Growth Chart Against Light Treatment

The phases of microalgae growth can be seen in (Figure 1.) In the lag phase, the light treatment which experienced significant growth occurred at a high light dose (7200 lux) with an average cell of 380,000 cells/ml while the lowest growth occurred at a light dose low (3600 lux) with an average cell of 256,000 cells/ml. In the exponential phase, the light treatment which experienced significant growth occurred at high light doses (7200 lux) starting from the 6th hour with an average cell of 380,000 cells/ml until it reached the optimal growth point at the 18th hour with an average cells, namely 1,418,000 cells/ml. Meanwhile the lowest cell growth occurs at low light doses (3600 lux) starting from the 6th hour with an average cell of 256,700 cells/ml until it reaches the optimal point of growth at the 18th hour with an average cell of 882,700 cells/ml ml.). In the stationary phase, the light treatment that experienced significant growth occurred at a high light dose (7200 lux) with an average cell of 710,000 cells/ml while the lowest growth occurred at a low light dose (3600 lux) with an average cell of 553,000 cells/ml.

Tabel 2. Growth data of *Skeletonema* sp. In Salinity treatment

P2	**Repitatio**	**Time (hours)**					**Number**	**Average**
		0	**6**	**12**	**18**	**24**		
SR	1	$42x10^3$	$201x10^3$	$516x10^3$	$702x10^3$	$460x10^3$	**$1.921x10^3$**	**$384.2x10^3$**
	2	$136x10^3$	$206x10^3$	$536x10^3$	$724x10^3$	$442x10^3$	**$2.044x10^3$**	**$408.8x10^3$**
	3	$130x10^3$	$186x10^3$	$498x10^3$	$698x10^3$	$403x10^3$	**$1.915x10^3$**	**$383x10^3$**
	Total	**$308x10^3$**	**$593x10^3$**	**$1.474x10^3$**	**$2.124x10^3$**	**$1.305x10^3$**	**$5.580x10^3$**	**$1.176x10^3$**
	Average	**$102.7x10^3$**	**$197.7x10^3$**	**$516.7x10^3$**	**$708x10^3$**	**$435x10^3$**	**$3.485x10^3$**	**$697x10^3$**
SS	1	$40x10^3$	$358x10^3$	$702x10^3$	$1.120x10^3$	$650x10^3$	**$2.870x10^3$**	**$574x10^3$**
	2	$130x10^3$	$348x10^3$	$698x10^3$	$1.020x10^3$	$598x10^3$	**$2.794x10^3$**	**$558.8x10^3$**
	3	$136x10^3$	$338x10^3$	$674x10^3$	$996x10^3$	$596x10^3$	**$2.730x10^3$**	**$546x10^3$**
	Total	**$306x10^3$**	**$1.044x10^3$**	**$2.074x10^3$**	**$3.136x10^3$**	**$1.834x10^3$**	**$8.394x10^3$**	**$1.678x10^3$**
	Average	**$102x10^3$**	**$348x10^3$**	**$692.7 x10^3$**	**$1.076. x10^3$**	**$611.3x10^3$**	**$2.797x10^3$**	**$559.5x10^3$**

ST	1	$41x10^3$	$180x10^3$	$388x10^3$	$616x10^3$	$498x10^3$	**$1.723x10^3$**	**$344.6x10^3$**
	2	$126x10^3$	$188x10^3$	$396x10^3$	$589x10^3$	$478x10^3$	**$1.777x10^3$**	**$355.4x10^3$**
	3	$130x10^3$	$190x10^3$	$398x10^3$	$598x10^3$	$488x10^3$	**$1.804x10^3$**	**$360.8x10^3$**
	Total	**$297x10^3$**	**$558x10^3$**	**$1.1.82x10^3$**	**$1.803x10^3$**	**$1.464x10^3$**	**$5.304x10^3$**	**$1.060x10^3$**
	Average	**$99x10^3$**	**$186x10^3$**	**$394x10^3$**	**$601x10^3$**	**$488x10^3$**	**$1.768x10^3$**	**$353.6x10^3$**

Information:

P2 : Salinity Treatment

SR : Low Salinity 26 ppt

SS : Moderate Salinity 28 ppt

ST : High Salinity 30 ppt

Based on the results of observations of the abundance of *Skeletonema* sp. based on the administration of different salinity treatments the highest was at the 18th hour which was located in the administration of medium salinity (SS) 28 ppt with an average cell of 1,405.000 cells/ml while the lowest abundance was at the 0th hour located in the high salinity treatment (ST) 30 ppt with an average cell of 99.000 cells/ml. (Table 2). There is an increase in the abundance of *Skeletonema* sp. This is due to the optimal salinity given at 28 ppt and also light rays which cause continuous cell division (Figure 2). According to experts (Herrera-Valencia et al., 2011; Hu et al., 2015; Piña et al., 2006; Yun et al., 2016), microalgae are also actors in the CO2 capture process in photobioreactors, therefore an understanding of Microalgae growth is important in the operation of a photobioreactor. Microalgae that grow rapidly during the operation of the photobioreactor are a reflection of the good performance of the photobioreactor.

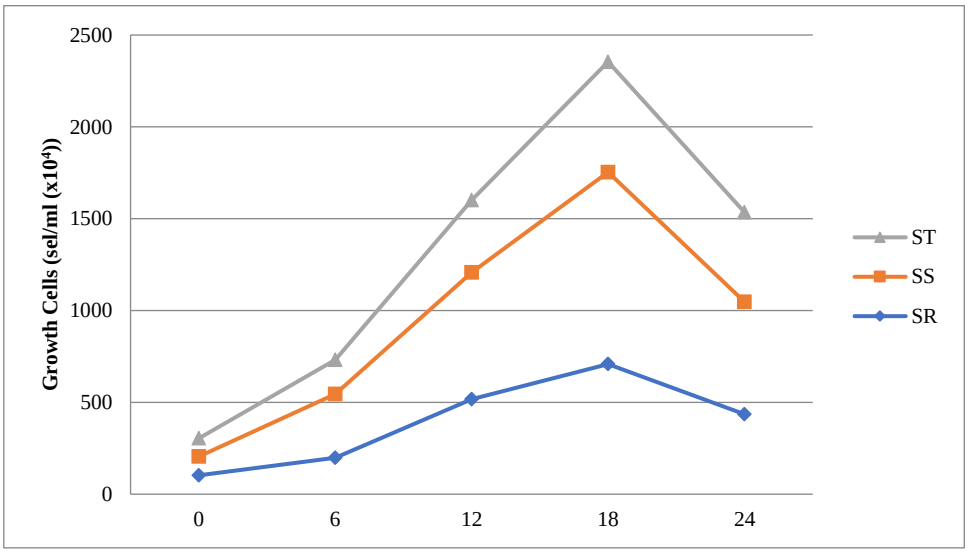

Figure 2. *Skeletonema* sp. Growth Chart Against Salinity Treatment

The phases of microalgae growth can be seen in (Figure 2.) In the lag phase, the salinity treatment which experienced significant growth occurred at a moderate salinity dose (28 ppt) with an average cell of 340,000 cells/ml while the lowest growth occurred at a salinity dose high (30 ppt) with an average cell of 186,000 cells/ml. In the exponential phase, the salinity treatment which experienced significant growth occurred at moderate salinity doses (28 ppt) starting from the 6th hour with an average cell of 380,000 cells/ml until it reached the optimal growth point at the 18th hour with an average cells, namely 1,418,000 cells/ml. Meanwhile the lowest cell growth occurs at hihg salinity doses (30 ppt) starting from the 6th hour with an average cell of 186,00 cells/ml until it reaches the optimal point of growth at the 18th hour with an average cell of 601.000 cells/ml). In the stationary phase, the salinity treatment that experienced significant growth occurred at a moderate salinity dose (28 ppt) with an average cell of 611,300 cells/ml while the lowest growth occurred at a low salinity dose (26 ppt) with an average cell of 435,000 cells/ml.

Table 3. *Skeletonema* sp. biomass production. due to different light treatments

Treatment	**Repetition**	**Time (hours)**			
		BB	**BK**	**BA**	**BIOMASSA**
CR	1	0.56	0.31	0.13	0.12
	2	0.57	0.32	0.13	0.12
	3	0.57	0.31	0.12	0.13

	Total	1.7	0.94	0.38	0.37
	Average	0.56	0.31	0.12	0.12
CS	1	0.64	0.33	0.15	0.16
	2	0.65	0.32	0.16	0.17
	3	0.67	0.33	0.16	0.18
	Total	1.96	0.98	0.47	0.51
	Average	**0.65**	**0.32**	**0.15**	**0.17**
CT	1	0.74	0.35	0.18	0.21
	2	0.76	0.34	0.17	0.25
	3	0.75	0.35	0.18	0.22
	Total	2.25	1.04	0.53	0.68
	Average	**0.75**	**0.34**	**0.17**	**0.2**

Table 4. *Skeletonema* sp. biomass production. as a result of different salinity treatments

Treatment	**Repetition**	**Time (hours)**			
		BB	**BK**	**BA**	**BIOMASSA**
SR	1	0.64	0.34	0.15	0.15
	2	0.64	0.33	0.14	0.17
	3	0.65	0.34	0.15	0.16
	Total	1.93	1.01	0.44	0.48
	Average	0.64	0.33	0.14	0.16
SS	1	0.70	0.34	0.16	0.2
	2	0.71	0.33	0.17	0.21
	3	0.70	0.34	0.17	0.19
	Total	2.11	1.01	0.5	0.6
	Average	**0.70**	**0.33**	**0.12**	**0.2**
ST	1	0.55	0.32	0.11	0.11
	2	0.5	0.31	0.11	0.12
	3	0.55	0.32	0.12	0.11
	Total	1.64	0.96	0.34	0.34
	Average	**0.54**	**0.32**	**0.11**	**0.11**

Information :
BA : Wet Weight
BK : Dry Weight
BA : Weight of Ash

Biomassa production is strongly influenced by the abundance of Skeletonema sp. the higher the abudance produced, based on Tables 3 and 4. This result in a graph of Skeletonema sp. biomass production. Increases from hour to hour according to the rate of growth it produces. The lowest biomass production was in the low light and high salinity treatment while the highest biomass production was in the high light and medium salinity treatment.

4. CONCLUTION

In the research conducted, it can be concluded that the effect of giving light and salinity treatment with different doses causes differences in the amount of cell growth and biomass production. It can be seen that the light treatment with a high dose of light (7200 lux) and the salinity treatment with a medium salinity dose (28 ppt) have better cell growth rates and biomass production compared to other doses with an average of cell in high light which is $141x10^4$ cells/ml and at moderate salinity, it is $107x10^4$ cells/ml, while for biomass production, the average weight of biomass at high light is 0.22 g/L and at medium salinity, it is 0.2 g/L.

References

Abrams, P. A., Adamec, R. E., Blundell, J., Burton, P., Adams, E. S., Adams, J. L., Camelio, K. W., Orique, M. J., Blumstein, D. T., Adler, F. R., Morris, W. F., Adler, G. H., Levins, R., Aebischer, N. J., Robertson, P. A., Kenward, R. E., Agrawal, A., Gibson, C. C., Aguilar, A., … Lima, S. L. (2001). Eradication of feral pigs from Australia. Conservation Biology, 10(1), 1–11. https://doi.org/10.2307/5616

Aldana-Aranda, D., & Patiño-Suárez, V. (1998). Overview of diets used in larviculture of three Caribbean conchs: Queen conch strombus gigas, milk conch Strombus costatus and Fighting Conch strombus pugilis. In Aquaculture (Vol. 167, Issues 3–4, pp. 163–178). https://doi.org/10.1016/S0044-8486(98)00304-4

Astuti, J. T., Sriwuryandari, L., Putro, E. A., & Sembiring, T. (2016). Growth And Fatty Acid Composition Of Marine Microalga Nannochloropsis Sp In Medium Enriched With Magnesium. Jurnal Teknologi Lingkungan.

Adawiyah, L. and H. Kenconojati. 2020. Growth Response of Porphyridium cruentum. Culture on Glass and Plastic Container in Laboratory Scale. Journal of Aquaculture and Fish Health. 9 (2): 155-163.

Agustini, N. W. dan Febrian. 2019. Hidrolisis Biomassa Mikroalga Porphyridium cruentum menggunakan Asam Sulfat (H2SO4) dan Asam Nitrat (HNO3) dalam Produksi Bioetanol. Jurnal Kimia dan Kemasan. 41 (1): 1-10.

Alim, I. dan Kurniastuty. 1995. Teknik Kultur Fitoplankton dan Zooplankton. Pakan Alam untuk Pembenihan Organisme Laut. Yogyakarta.

Arad, S. M. and A. Richmond. 2004. Industrial Production of Microalgae and Secondary Products-Species of High Potential Porphyridium cruentum. Handbook of Microalgae Cultures Biotechnology and Applied Phycology. United Kingdom.

Ariyanti, D. dan N. A. Handayani, 2010. Mikroalga Sebagai Sumber Biomassa Terbarukan. 6 (2).

Ariyanti, D. dan A. H. Noer. Potensi Mikroalga Sebagai Sumber Biomassa dan Pengembangan Produk Turunannya. 33 (2).

Armanda, D. T. 2013. Pertumbuhan Kultur Mikroalga Diatom Porphyridium cruentum Cleve Isolat Jepara pada Medium F/2 dan Medium Conway. Bioma. 2 (1): 49-63.

Assadad, L. dan R. N. Sari. 2010. Pemanfaatan Mikroalga Sebagai Bahan Baku Bioetanol. Squalen. 5 (2): 51-58.

Beatrice-Lindner, P., Garrido-Cardenas, J. A., Sepulveda, C., & Acien-Fernandez, F. G. (2018). A new approach for detection and quantification of microalgae in industrial-scale microalgal cultures. Applied Microbiology and Biotechnology, 102(19). https://doi.org/10.1007/s00253-018-9268-y

Brooks, E. G. E., Holland, R. A. R. a. R. a., Darwall, W. R. T. W. R. T., Eigenbrod, F., Wunder, S., Angelsen, A., Belcher, B., Chaplin-Kramer, R., Dombeck, E., Gerber, J., Knuth, K. A., Mueller, N. D., Mueller, M., Ziv, G., Klein, A. M., Suich, H., Howe, C., Mace, G. M., Martinez-Harms, M. J., … Gaston, K. J. (2010). Global impacts of energy demand on the freshwater resources of nations. Biological Conservation, 21(2), n/a-n/a. https://doi.org/10.1890/120144

Burton, N. H. K., Rehfisch, M. M., Clark, N. A., Dodd, S. G., Crivelli, A. J., Grillas, P., Jerrentrup, H., Nazirides, T., Deangelis, D. L., Grimm, V., Ens, B. J., Piersma, T., Drent, R. H., Evans, P. R., Ward, R. M., Bone, M., Leakey, M., FAOFishFinder, Fujii, T., … Wilensky, U. (2012). Reclamation of intertidal land: some effects on Shelduck and wader populations in the Tees estuary. Journal of Applied Ecology, 367(1), 163–174. https://doi.org/10.1023/A:1022139600926

Cagnon, C., Mirabella, B., Nguyen, H. M., Beyly-Adriano, A., Bouvet, S., Cuiné, S., Beisson, F., Peltier, G., & Li-Beisson, Y. (2013). Development of a forward genetic screen to isolate oil mutants in the green microalga Chlamydomonas reinhardtii. Biotechnology for Biofuels, 6(1). https://doi.org/10.1186/1754-6834-6-178

Chowdhury, M. A., Khairun, Y., Rahman, M. M., & Shivakoti, G. P. (2010). Production economics as an indicator for sustainable development of shrimp farming. Asia-Pacific Journal of Rural Development.

Cunningham, E. M. (1992). Seaweeds: Their Environment, Biogeography, and Ecophysioiogy. Phycologia. https://doi.org/10.2216/i0031-8884-31-3-4-367.1

D'Archino, R., & Piazzi, L. (2021). Macroalgal assemblages as indicators of the ecological status of marine coastal systems: A review. Ecological Indicators, 129.

Damiani, M. C., Popovich, C. A., Constenla, D., & Leonardi, P. I. (2010). Lipid analysis in Haematococcus pluvialis to assess its potential use as a biodiesel feedstock. In Bioresource Technology (Vol. 101, Issue 11, pp. 3801–3807). https://doi.org/10.1016/j.biortech.2009.12.136

De Bhowmick, G., Subramanian, G., Mishra, S., & Sen, R. (2014). Raceway pond cultivation of a marine microalga of Indian origin for biomass and lipid production: A case study. Algal Research, 6(PB), 201–209. https://doi.org/10.1016/j.algal.2014.07.005

Dennison, W. C. (1987). Effects of light on seagrass photosynthesis, growth and depth distribution. Aquatic Botany, 27(1), 15–26. https://doi.org/10.1016/0304-3770(87)90083-0

Doan, T. T. Y., Sivaloganathan, B., & Obbard, J. P. (2011). Screening of marine microalgae for biodiesel feedstock. Biomass and Bioenergy, 35(7), 2534–2544. https://doi.org/10.1016/j.biombioe.2011.02.021

Duarte, M. H. L., Sousa-Lima, R. S., Young, R. J., Farina, A. A., Vasconcelos, M. J., Rodrigues, M., Pieretti, N., Lagomasino, D., Fatoyinbo, T. E., Lee, S.-K. S. S. K., Simard, M., Dwyer, E., Pinnock, S., Gregoire, J. M., Pereira, J. M. C., Calandra, D. M., Mauro, D. Di, Cutugno, F., Martino, S. Di, … Romancuesta, R. (2017). TB Brown. Remote Sensing of Environment, 8(1), 1–12. https://doi.org/10.1023/A

El-Sheekh, M., Abomohra, A. E. F., & Hanelt, D. (2013). Optimization of biomass and fatty acid productivity of Scenedesmus obliquus as a promising microalga for biodiesel production. World Journal of Microbiology and Biotechnology, 29(5), 915–922. https://doi.org/10.1007/s11274-012-1248-2

Fuentes, M. M. R. and J. L. G. Guerrero. 2000. Biomassa Nutrient Profiles of Microalgae Porphyridium cruentum. Food Chemistry. 70 (52): 345-353.

Grima, E. M. and A. R. Medina. 2004. Downstream Processing of Cell-mass and Products. Handbook of Microalgal Cultures Biotechnology and Applied Phycology. United Kingdom.

Hariyati, R. 2008. Pertumbuhan dan Biomassa Porphyridium cruentum dalam Skala Laboratorium. Laboratorium Ekologi dan Biosistematik Jurusan Biologi FMIPA Undip. Bioma. 10 (1): 19-22.

Harun, R. and M. K. Danquah. 2010. Microalgae Biomass as a Cellulosic Fermentation Feedstock for Bioethanol Production. Renewable and Sustainable Energy Review. 14 (10): 1343-1352.

Hart, P. J. B., & Reynolds, J. D. (2002). Banishing ignorance: Underpinning fisheries with basic biology . Handbook of Fish Biology and Fisheries; Volume 1: Fish Biology , 1, 1–11. https://doi.org/10.1002/9780470693803.ch1

Herrera-Valencia, V. A., Contreras-Pool, P. Y., López-Adrián, S. J., Peraza-Echeverría, S., & Barahona-Pérez, L. F. (2011). The Green Microalga Chlorella saccharophila as a Suitable Source of Oil for Biodiesel Production. Current Microbiology, 63(2), 151–157. https://doi.org/10.1007/s00284-011-9956-7

Holbrook, G. P., Davidson, Z., Tatara, R. A., Ziemer, N. L., Rosentrater, K. A., & Scott Grayburn, W. (2014). Use of the microalga Monoraphidium sp. grown in wastewater as a feedstock for biodiesel: Cultivation and fuel characteristics. Applied Energy, 131, 386–393. https://doi.org/10.1016/j.apenergy.2014.06.043

Hu, Q., Xiang, W., Dai, S., Li, T., Yang, F., Jia, Q., Wang, G., & Wu, H. (2015). The influence of cultivation period on growth and biodiesel properties of microalga Nannochloropsis gaditana 1049. Bioresource Technology, 192, 157–164. https://doi.org/10.1016/j.biortech.2015.04.106

Jang, S., Yamaoka, Y., Ko, D. hwi, Kurita, T., Kim, K., Song, W. Y., Hwang, J. U., Kang, B. H., Nishida, I., & Lee, Y. (2015). Characterization of a Chlamydomonas reinhardtii mutant defective in a maltose transporter. Journal of Plant Biology. https://doi.org/10.1007/s12374-015-0377-1

Jati, F., H. Johanes dan E. H. Vivi. 2012. Pengaruh Penggunaan Dua Jenis Media Kultur yang Berbeda terhadap Pola Pertumbuhan, Kandungan Protein dan Asam Lemak Omega. Jurnal of Aquaculture Management and Technology. 1 (2): 221-235.

Jena, J., Pradhan, N., Aishvarya, V., Nayak, R. R., Dash, B. P., Sukla, L. B., Panda, P. K., & Mishra, B. K. (2015). Biological sequestration and retention of cadmium as CdS nanoparticles by the microalga Scenedesmus-24. Journal of Applied Phycology. https://doi.org/10.1007/s10811-014-0499-8

Ji, M.-K., Abou-Shanab, R. A. I., Hwang, J.-H., Timmes, T. C., Kim, H.-C., Oh, Y.-K., & Jeon, B.-H. (2013). Removal of Nitrogen and Phosphorus from Piggery Wastewater Effluent Using the Green Microalga Scenedesmus obliquus. Journal of Environmental Engineering. https://doi.org/10.1061/(ASCE)EE.1943-7870.0000726

Johnson, M. B., & Wen, Z. (2009). Production of Biodiesel Fuel from the Microalga Schizochytrium limacinum by Direct Transesterification of Algal Biomass. Energy & Fuels, 23(10), 5179–5183. https://doi.org/10.1021/ef900704h

Khaeratul, Z. 2019. Uji Aktivitas Antioksidan Ekstra Mikroalga Porphyridium cruentum Menggunakan Metode Perendam Radikal Bebas DPPH.

Kosasih, Y. 2011. Aktivitas Antibakteri Mikroalga Porphyridium cruentum terhadap berbagai Jenis Bakteri Patogen. Skripsi. Institut Pertanian Bogor.

Kusumawarni E. 1998. Mempelajari Pengaruh Intensitas Terhadap Pertumbuhan Sel, Produksi Polisakarida dan Pigmen dari Mikroalga Porphyridium cruentum. Skripsi. Bogor. 43 hal.

Kepala Badan Penelitian dan Pengembangan Pertanian, H. (2013). Strategi Kebijakan Kementrian Pertanian dalam Optimalisasi Lahan Suboptimal Mendukung Ketahanan Pangan Nasional (Issue September).

Kim, K. H., Choi, I. S., Kim, H. M., Wi, S. G., & Bae, H. J. (2014). Bioethanol production from the nutrient stress-induced microalga Chlorella vulgaris by enzymatic hydrolysis and immobilized yeast fermentation. Bioresource Technology. https://doi.org/10.1016/j.biortech.2013.11.059

Kiran, B., Pathak, K., Kumar, R., & Deshmukh, D. (2016). Statistical optimization using Central Composite Design for biomass and lipid productivity of microalga: A step towards enhanced biodiesel production. Ecological Engineering, 92, 73–81. https://doi.org/10.1016/j.ecoleng.2016.03.026

Kojima, E., & Zhang, K. (1999). Growth and hydrocarbon production of microalga Botryococcus braunii in bubble column photobioreactors. Journal of Bioscience and Bioengineering, 87(6), 811–815. https://doi.org/10.1016/S1389-1723(99)80158-3

Kumar, L., Roy, A., Saxena, G., Kundu, K., & Bharadvaja, N. (2017a). Isolation, Identification and biomass productivity analysis of microalga Scenedesmus rubescens from DTU Lake. J. Algal Biomass Utln, 8(3), 56–67. http://jalgalbiomass.com/paper8vol8no3.pdf

Kumar, L., Roy, A., Saxena, G., Kundu, K., & Bharadvaja, N. (2017b). Isolation, Identification and biomass productivity analysis of microalga Scenedesmus rubescens from DTU Lake. J. Algal Biomass Utln, 8(3).

Le, C., Zha, Y., Li, Y., Sun, D., Lu, H., & Yin, B. (2010). Eutrophication of lake waters in China: Cost, causes, and control. In Environmental Management. https://doi.org/10.1007/s00267-010-9440-3

Li, Y., Chen, Y. F., Chen, P., Min, M., Zhou, W., Martinez, B., Zhu, J., & Ruan, R. (2011). Characterization of a microalga Chlorella sp. well adapted to highly concentrated municipal wastewater for nutrient removal and biodiesel production. Bioresource Technology, 102(8), 5138–5144. https://doi.org/10.1016/j.biortech.2011.01.091

Matsumoto, M., Sugiyama, H., Maeda, Y., Sato, R., Tanaka, T., & Matsunaga, T. (2010). Marine diatom, Navicula sp. strain JPCC DA0580 and marine green alga, Chlorella sp. Strain NKG400014 as potential sources for biodiesel production. Applied Biochemistry and Biotechnology, 161(1–8), 483–490. https://doi.org/10.1007/s12010-009-8766-x

Molina-Miras, A., Morales-Amador, A., de Vera, C. R., López-Rosales, L., Sánchez-Mirón, A., Souto, M. L., Fernández, J. J., Norte, M., García-Camacho, F., & Molina-Grima, E. (2018). A pilot-scale bioprocess to produce amphidinols from the marine microalga Amphidinium carterae: Isolation of a novel analogue. Algal Research, 31. https://doi.org/10.1016/j.algal.2018.01.010

Montero, M. F., Aristizábal, M., & García Reina, G. (2011). Isolation of high-lipid content strains of the marine microalga Tetraselmis suecica for biodiesel production by flow cytometry and single-cell sorting. Journal of Applied Phycology, 23(6), 1053–1057. https://doi.org/10.1007/s10811-010-9623-6

Moore, K. A., & Wetzel, R. L. (2000). Seasonal variations in eelgrass (Zostera marina L.) responses to nutrient enrichment and reduced light availability in experimental ecosystems. Journal of Experimental Marine Biology and Ecology, 244(1), 1–28. https://doi.org/10.1016/S0022-0981(99)00135-5

Padang, A., La. A. dan H. Latuconsina. 2013. Pengaruh Intensitas Cahaya yang Berbeda terhadap Pertumbuhan Navicula sp. Skala Laboratorium. Jurnal BIMAFIKA ISSN. 560-565.

Padang, A., Radjab. A. dan N. Jafar. 2015. Pertumbuhan Fitoplankton Nannochloropsis sp. dengan Perlakuan Intesitas Cahaya Lampu TL yang berbeda. IPTEK Perikanan dan Kelautan Universitas Pattimura. Ambon.

Patil, V., Tran. K.Q. and H. Giserold. 2008. Towards Sustainable Production of Biodiesels From Microalgae. Int. J. Mol. Sci. (9): 1158-1195.

Peng, L. H., Unnikrishnan, B., Shih, C. Y., Hsiung, T. M., Chang, J., Hsu, P. H., Chiu, T. C., & Huang, C. C. (2016). Identification of Microalgae by Laser Desorption/Ionization Mass Spectrometry Coupled with Multiple Nanomatrices. Marine Biotechnology, 18(2). https://doi.org/10.1007/s10126-016-9685-9

Piña, P., Voltolina, D., Nieves, M., & Robles, M. (2006). Survival, development and growth of the Pacific white shrimp Litopenaeus vannamei protozoea larvae, fed with monoalgal and mixed diets. Aquaculture. https://doi.org/10.1016/j.aquaculture.2005.07.016

Popovich, C. A., Damiani, C., Constenla, D., Martínez, A. M., Freije, H., Giovanardi, M., Pancaldi, S., & Leonardi, P. I. (2012). Neochloris oleoabundans grown in enriched natural seawater for biodiesel feedstock: Evaluation of its growth and biochemical composition. Bioresource Technology, 114, 287–293. https://doi.org/10.1016/j.biortech.2012.02.121

Potensi Antibakteri Diatom Laut Skeletonema costatum terhadap Bakteri Vibrio sp. (2006). Jurnal Pengolahan Hasil Perikanan Indonesia. https://doi.org/10.17844/jphpi.v9i1.1006

Radhakrishnan, S., Belal, I. E. H., Seenivasan, C., Muralisankar, T., & Bhavan, P. S. (2016). Impact of fishmeal replacement with Arthrospira platensis on growth performance, body composition and digestive enzyme activities of the freshwater prawn, Macrobrachium rosenbergii. Aquaculture Reports. https://doi.org/10.1016/j.aqrep.2015.11.005

Rattanapoltee, P., & Kaewkannetra, P. (2014). Cultivation of microalga, Chlorella vulgaris under different auto-hetero-mixo trophic growths as a raw material during biodiesel production and cost evaluation. Energy, 78, 4–8. https://doi.org/10.1016/j.energy.2014.06.049

Reis Batista, I., Garcia, A. B., van Dalen, P., Kamermans, P., Verdegem, M., & Smaal, A. C. (2015). Culturing Chaetoceros muelleri using simplified media with different N sources: effects on production and lipid content. European Journal of Phycology. https://doi.org/10.1080/09670262.2014.994137

Ren, H. Y., Liu, B. F., Ma, C., Zhao, L., & Ren, N. Q. (2013). A new lipid-rich microalga Scenedesmus sp. strain R-16 isolated using Nile red staining: Effects of carbon and nitrogen sources and initial pH on the biomass and lipid production. Biotechnology for Biofuels, 6(1). https://doi.org/10.1186/1754-6834-6-143

Sari, F. Y. A., I. M. A. Suryajaya dan Hadiyanto. 2012. Kultivasi Mikroalga Porphyridium cruentum dalam Media POME dengan Variasi Konsentrasi POME dan Komposisi Jumlah Nutrien. Jurnal Teknologi Kimia dan Industri. 1 (1): 487-494.

Soeprobowati, T. R. dan H. Riche. 2013. Potensi Mikroalga sebagai Agen Bioremediasi dan Aplikasinya dalam Penurunan Konsentrasi Logam Berat pada Instalasi Pengolah Air Limbah Industri. Laporan Penelitian.

Sabeela Beevi, U., & Sukumaran, R. K. (2014). Cultivation of the fresh water microalga Chlorococcum sp. RAP13 in sea water for producing oil suitable for biodiesel. Journal of Applied Phycology, 27(1), 141–147. https://doi.org/10.1007/s10811-014-0340-4

Song, M., Pei, H., Hu, W., Zhang, S., Ma, G., Han, L., & Ji, Y. (2014). Identification and characterization of a freshwater microalga Scenedesmus SDEC-8 for nutrient removal and biodiesel production. Bioresource Technology, 162, 129–135. https://doi.org/10.1016/j.biortech.2014.03.135

St. John, M. A., & Lund, T. (1996). Lipid biomarkers: Linking the utilization of frontal plankton biomass to enhanced condition of juvenile North Sea cod. Marine Ecology Progress Series. https://doi.org/10.3354/meps131075

Surendhiran, D., Vijay, M., & Sirajunnisa, A. R. (2014). Biodiesel production from marine microalga Chlorella salina using whole cell yeast immobilized on sugarcane bagasse. Journal of Environmental Chemical Engineering, 2(3), 1294–1300. https://doi.org/10.1016/j.jece.2014.05.004

Sutomo. (2013). Struktur Komunitas Fitoplankton Di Perairan Teluk Sekotong Dan Teluk Kodek, Kabupaten Lombok. Jurnal Ilmu Dan Teknologi Kelautan Tropis, 5(1), 131–144.

Takara, T., Nakagawa, T., Isobe, M., Okino, N., Ichinose, S., Omori, A., & Ito, M. (2011). Purification, molecular cloning, and application of a novel sphingomyelin-binding protein (clamlysin) from the brackishwater clam, Corbicula japonica. Biochimica et Biophysica Acta - Molecular and Cell Biology of Lipids, 1811(5), 323–332. https://doi.org/10.1016/j.bbalip.2011.02.004

Tjahjo, W., L. Erawati. dan S. Hanung. 2002. Budidaya Fitoplankton dan Zooplankton. Direktorat Jendral Perikanan Budidaya Departemen Kelautan dan Perikanan. Pengembangan Perekayasaan Ekologi Balai Budidaya Laut Lampung.

Tripathi, R., Singh, J., & Thakur, I. S. (2015). Characterization of microalga Scenedesmus sp. ISTGA1 for potential CO2 sequestration and biodiesel production. Renewable Energy, 74, 774–781. https://doi.org/10.1016/j.renene.2014.09.005

Weng, Q., Wang, J. J. J. J. J. J. J. W. J. J., Sammis, T. W., Andales, A. A., Simmons, L. J., Gutschick, V. P., Miller, D. R., Waser, L. T., Ginzler, C., Kuechler, M., Baltsavias, E., Hurni, L., Walker, W. S., Kellndorfer, J. M., Pierce, L. E., Schneebeli, M., Wolf, S., Kunert, N., Eugster, W., … Duveiller, G. (2008). Estimation of tree canopy cover in evergreen oak woodlands using remote sensing. Remote Sensing of Environment, 3, 1–4. https://doi.org/10.1111/j.1529-8817.2003.00756.x

Winder, M., Berger, S. A., Lewandowska, A., Aberle, N., Lengfellner, K., Sommer, U., & Diehl, S. (2012). Spring phenological responses of marine and freshwater plankton to changing temperature and light conditions. Marine Biology, 159(11), 2491–2501. https://doi.org/10.1007/s00227-012-1964-z

Xin, L., Hong-ying, H., & Jia, Y. (2010). Lipid accumulation and nutrient removal properties of a newly isolated freshwater microalga, Scenedesmus sp. LX1, growing in secondary effluent. New Biotechnology, 27(1), 59–63. https://doi.org/10.1016/j.nbt.2009.11.006

Xin, L., Hong-ying, H., Ke, G., & Jia, Y. (2010). Growth and nutrient removal properties of a freshwater microalga Scenedesmus sp. LX1 under different kinds of nitrogen sources. Ecological Engineering. https://doi.org/10.1016/j.ecoleng.2009.11.003

Xin, L., Hong-ying, H., Ke, G., & Ying-xue, S. (2010). Effects of different nitrogen and phosphorus concentrations on the growth, nutrient uptake, and lipid accumulation of a freshwater microalga Scenedesmus sp. Bioresource Technology, 101(14), 5494–5500. https://doi.org/10.1016/j.biortech.2010.02.016

Xin, L., Hong-ying, H., & Yu-ping, Z. (2011). Growth and lipid accumulation properties of a freshwater microalga Scenedesmus sp. under different cultivation temperature. Bioresource Technology, 102(3), 3098–3102. https://doi.org/10.1016/j.biortech.2010.10.055

Xin, L., Hu, H., Ke, G., & Sun, Y. (2010). Effects of different nitrogen and phosphorus concentrations on the growth, nutrient uptake, and lipid accumulation of a freshwater microalga Scenedesmus sp. Bioresource Technology, 101(14), 5494–5500. https://doi.org/10.1016/j.biortech.2010.02.016

Xu, H., Miao, X., & Wu, Q. (2006). High quality biodiesel production from a microalga Chlorella protothecoides by heterotrophic growth in fermenters. Journal of Biotechnology, 126(4), 499–507. https://doi.org/10.1016/j.jbiotec.2006.05.002

Xue, J., Niu, Y. F., Huang, T., Yang, W. D., Liu, J. S., & Li, H. Y. (2015). Genetic improvement of the microalga Phaeodactylum tricornutum for boosting neutral lipid accumulation. Metabolic Engineering, 27, 1–9. https://doi.org/10.1016/j.ymben.2014.10.002

Yang, J., Li, X., Hu, H., Zhang, X., Yu, Y., & Chen, Y. (2011). Growth and lipid accumulation properties of a freshwater microalga, Chlorella ellipsoidea YJ1, in domestic secondary effluents. Applied Energy, 88(10), 3295–3299. https://doi.org/10.1016/j.apenergy.2010.11.029

Yeh, K. L., & Chang, J. S. (2012). Effects of cultivation conditions and media composition on cell growth and lipid productivity of indigenous microalga Chlorella vulgaris ESP-31. Bioresource Technology, 105, 120–127. https://doi.org/10.1016/j.biortech.2011.11.103

Yun, H. S., Ji, M. K., Park, Y. T., Salama, E. S., & Choi, J. (2016). Microalga, Acutodesmus obliquus KGE 30 as a potential candidate for CO2mitigation and biodiesel production. Environmental Science and Pollution Research, 23(17), 17831–17839. https://doi.org/10.1007/s11356-016-6971-z

Zhang, X., Lin, Y. H., Surratt, J. D., Zotter, P., Prévôt, A. S. H., & Weber, R. J. (2011). Light-absorbing soluble organic aerosol in Los Angeles and Atlanta: A contrast in secondary organic aerosol. Geophysical Research Letters, 38(21). https://doi.org/10.1029/2011GL049385

Zimmerman, R. C. (2006). Light and photosynthesis in seagrass meadows. In Seagrasses: Biology, Ecology and Conservation (pp. 303–321). https://doi.org/10.1007/978-1-4020-2983-7_13