Title: **The Conceptual Design of Stream Island Index for Physical Habitat Complexity Assessment in Stream Restoration Projects**

1. Draft paper disubmit ke Jurnal Internasional Bereputasi
   - Confirming submission to Frontiers in Built Environment, section Sustainable Design and Construction (31 Agustus 2023) dengan bukti sebagai berikut:

Your manuscript submission - 1286484

Frontiers Built Environment Editorial Office
To me

Manuscript
Research Topic

31 Aug 2023 10:22 AM (GMT)

Dear Dr Tallar

We are pleased to inform you that we have received the manuscript "The Conceptual Design of Stream Island Index (SII): Template for Physical Habitat Complexity Assessment in Stream Restoration Projects" to be considered for publication in Frontiers in Built Environment, section Sustainable Design and Construction.

You can access the review forum and track the progress of your manuscript using the following link:
https://www.frontiersin.org//Journal/MySubmission.aspx?stage=100

Your manuscript is now in the initial validation stage to determine its suitability for peer review. Should your manuscript be sent out for peer review, you will receive a notification once we receive the reports from reviewers and the interactive review forum is activated. You will then be able to read

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Best regards,
Your Frontiers in Built Environment Team,

Frontiers | Editorial Office - Collaborative Peer Review Team
www.frontiersin.org
Avenue du Tribunal Fédéral 34
1005 Lausanne Switzerland

For technical issues please contact our IT Helpdesk (support@frontiersin.org) or visit our Frontiers Help Center (helpcenter.frontiersin.org)

-----------MANUSCRIPT DETAILS-----------
Manuscript title: The Conceptual Design of Stream Island Index (SII): Template for Physical Habitat Complexity Assessment in Stream Restoration Projects
Manuscript ID: 1286484
Authors: Robby Yussac Tallar
Journal: Frontiers in Built Environment, section Sustainable Design and Construction
Article type: Original Research
Submitted on: 31 Aug 2023
Research Topic: Sustainable Urban Living with Adaptation Measures in Anticipation Against Climate Change

-----------ADDITIONAL INFORMATION-----------
In order to enable a smooth and efficient review process, please familiarize yourself with the Frontiers review guidelines:
https://www.frontiersin.org/Journal/ReviewGuidelines.aspx?s=1641&name=sustainable_design_and_construction

To take part in the Resource Identification Initiative please cite antibodies, genetically modified organisms, software tools, data, databases and services using the corresponding catalog number and RRID in the text of your article. Please see here for more information:
https://www.frontiersin.org//files/pdf/letter_to_author.pdf
If you encounter any technical issue, contact support@frontiersin.org, with KOTTL95OFtoIYr9 as

2. Editorial assignment start date 1 Sept 2023 (**BUKTI 1 LAMPIRAN KORESPONDENSI EDITOR DENGAN AUTHOR DISERTAI HASIL REVIEW**)
3. Independent review start date 3 Sept 2023(**BUKTI 1 LAMPIRAN KORESPONDENSI EDITOR DENGAN AUTHOR DISERTAI HASIL REVIEW**)

Frontiers Built Environment Editorial Office
To me

M Manuscript
R Research Topic

13 Sep 2023 10:12 AM (GMT)

Dear Dr Tallar,

A new review report has been submitted by a Reviewer 1. Once the other Reviewer(s) have submitted their comments, you will be granted access to the reports in the review forum, so that you can begin your revisions. Please be ready to respond and revise your manuscript promptly when they do.

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Manuscript ID: 1286484
Authors: Robby Yussac Tallar
Journal: Frontiers in Built Environment, section Sustainable Design and Construction
Article type: Original Research
Submitted on: 31 Aug 2023

Independent Review Report, Reviewer 1

EVALUATION

Please list your revision requests for the authors and provide your detailed comments, including highlighting limitations and strengths of the study and evaluating the validity of the methods, results, and data interpretation. If you have additional comments based on Q2 and Q3 you can add them as well.

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Check List

a. Is the quality of the figures and tables satisfactory?

Yes

b. Does the reference list cover the relevant literature adequately and in an unbiased manner?

Yes

c. Are the statistical methods valid and correctly applied? (e.g. sample size, choice of test)

Yes

d. Is a statistician required to evaluate this study?

No

e. Are the methods sufficiently documented to allow replication studies?

Yes

QUALITY ASSESSMENT:

Rigor

4

Quality of the writing

4

Overall quality of the content

4

Interest to a general audience

5

Independent Review Report, Reviewer 2
EVALUATION
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QUALITY ASSESSMENT:
Rigor
5
Quality of the writing
4
Overall quality of the content
5
Interest to a general audience
4

4. Review results 13 Sept 2023 **(BUKTI 1 LAMPIRAN KORESPONDENSI EDITOR DENGAN AUTHOR DISERTAI HASIL REVIEW)**
5. Revisi ditagih (menjawab hasil review dri reviewers) 17 Sept 2023

Frontiers Built Environment Editorial Office
To me

Manuscript
Research Topic

13 Sep 2023 10:12 AM (GMT)

Dear Dr Tallar,

I'm contacting you to request your action on your manuscript "The Conceptual Design of Stream Island Index (SII): Template for Physical Habitat Complexity Assessment in Stream Restoration Projects" submitted to Frontiers in Built Environment, section Sustainable Design and Construction.

Please access the review forum using the link below to respond to the comments in the Editor's tab and resubmit the revised manuscript by 17 Sep 2023. We encourage you to submit your revised manuscript with tracked changes to facilitate the review.

http://review.frontiersin.org/review/1286484/0/0

The review process is almost complete and we look forward to receiving your response in time. Should you require more time please do not hesitate to contact the editorial office.

Best regards,

6. Revisi ditagih oleh editor

Action needed: your reply to the editor's request - 1286484

Frontiers Built Environment Editorial Office
To me

M Manuscript
R Research Topic

17 Sep 2023 10:12 AM (GMT)

Dear Dr Tallar,

This is to remind you that your response to the editor Alfrendo Satyanaga is overdue. Please visit the review forum using the link below and address the editor's comments as soon as possible:
https://review.frontiersin.org/review/bootstrap/91277dc0-b2fb-4ea1-a55e-7c7c514095e3

If you need to resubmit a revised version of your manuscript, we encourage you to first respond to the Editor's comments highlighting all the changes that you have made.

Please then submit your revised manuscript with tracked changes to highlight the revisions. Always ensure that both manuscript files (Word DOC or LaTex and PDF) are identical in content when submitting your revisions.

7. Revisi dilakukan dan submit 20 September 2023 **(BUKTI 2: RESPONSE TO REVIEWER 1 AND REVIEWER 2 BESERTA REVISI DRAFT PAPER)**

8. Paper diterima 25 September 2023

Frontiers Built Environment Editorial Office via Frontiers: Your manuscript is accepted - 1286484

Frontiers Built Environment Editorial Office
To me

M Manuscript

25 Sep 2023 02:02 PM (GMT)

Dear Dr Tallar,

I am pleased to inform you that your manuscript "The Conceptual Design of Stream Island Index for Physical Habitat Complexity Assessment in Stream Restoration Projects" has been approved for production and accepted for publication in Frontiers in Built Environment, section Sustainable Design and Construction.
Proofs are being prepared for you to verify before publication. We will also perform final checks to ensure your manuscript meets our criteria for publication (https://www.frontiersin.org/about/review-system#ManuscriptQualityStandards).

9. Reading Proof 7 Oktober 2023

Built Environment Production Office via Frontiers: Your proof is ready for checking

Built Environment Production Office M Manuscript
To me
05 Oct 2023 12:54 PM (GMT)

Dear Robby Tallar,

I just finished preparing the proof of your article "The Conceptual Design of Stream Island Index for Physical Habitat Complexity Assessment in Stream Restoration Projects", DOI: 10.3389/fbuil.2023.1286484. Please check it within 48 hours (excluding weekends and holidays) and make sure to respond in the system so that I'm notified of your corrections. We do accept corrections after this timeframe but please provide them as soon as possible to avoid delays in production.

Here's the link:
http://www.frontiersin.org/Production/EnterProductionForum.aspx?activationno=72f5972f-ce39-4f6f-90a1-319b5116bc84&pagekey=POF_DISCUSSION_FORUM

Built Environment Production Office via Frontiers: You've got a message from the type-setters

Built Environment Production Office M Manuscript
To me
07 Oct 2023 03:07 PM (GMT)

Dear Robby Yussac Tallar,

The type-setter has posted the following message in the proof discussion of your article "The Conceptual Design of Stream Island Index for Physical Habitat Complexity Assessment in Stream Restoration Projects" (10.3389/fbuil.2023.1286484):

Query

Dear Authors,

10. Paper dipublished 13 Oktober 2023

Built Environment Production Office via Frontiers: Congratulations! Your article is published

Built Environment Production Office Manuscript

To me

13 Oct 2023 04:04 AM (GMT)

Dear Robby Y. Tallar,

Congratulations on the publication of your open access article: The Conceptual Design of Stream Island Index for Physical Habitat Complexity Assessment in Stream Restoration Projects, by Robby Yussac Tallar, published in Frontiers in Built Environment, section Sustainable Design and Construction.

To view the online publication, please click here:

To view the online publication, please click here:

http://journal.frontiersin.org/article/10.3389/fbuil.2023.1286484/full?&utm_source=Email_to_authors_&utm_medium=Email&utm_content=T1_11.5e1_author&utm_campaigr

Please let us know about your authoring experience via a 3-minutes survey so we can better meet scientists' expectations for future submissions:

https://frontiersin.qualtrics.com/jfe/form/SV_9otESMXKfUOvtsi?ArticleID=1286484&LoopID=1484704&RoleID=16&JournalName=Frontiers%20in%20Built%20Environmer

We look forward to your feedback and future submissions.

Best regards,

Frontiers Built Environment Production Office
builtenvironment.production.office@frontiersin.org
www.frontiersin.org

For technical issues, please contact our Application Support team - support@frontiersin.org

BUKTI 1 LAMPIRAN KORESPONDENSI EDITOR DENGAN AUTHOR DISERTAI HASIL REVIEW

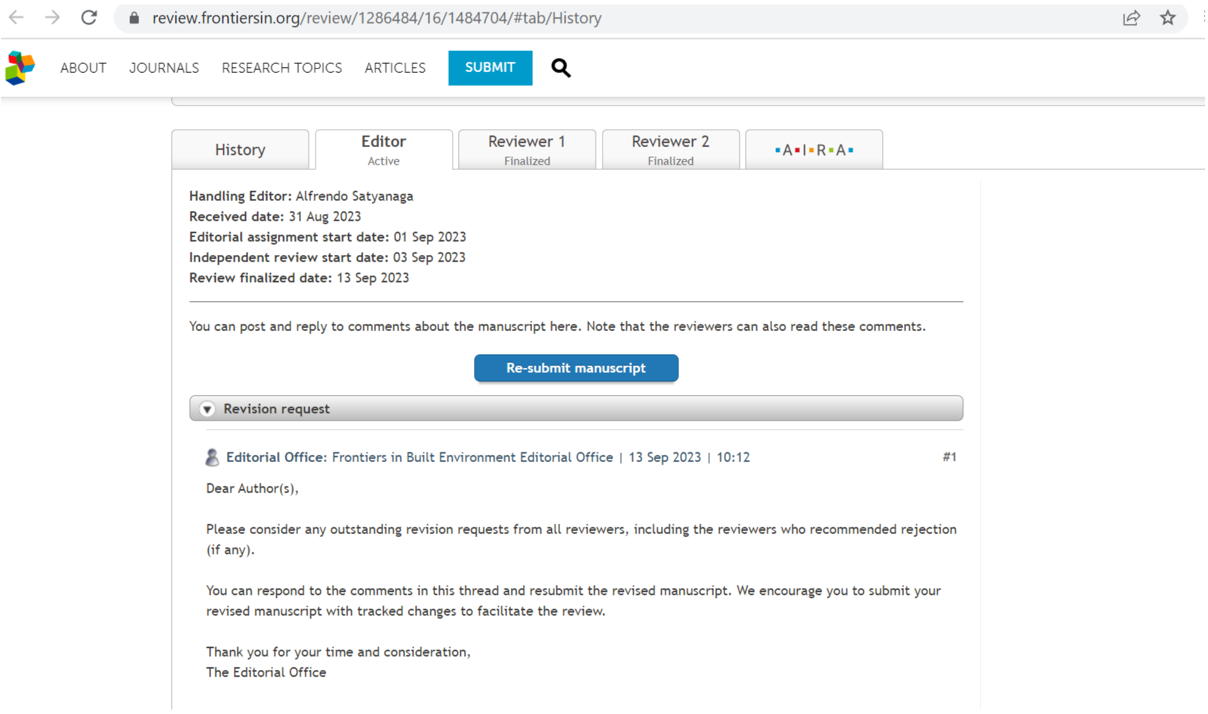
Dear Author(s),

Please consider any outstanding revision requests from all reviewers, including the reviewers who recommended rejection (if any).

You can respond to the comments in this thread and resubmit the revised manuscript. We encourage you to submit your revised manuscript with tracked changes to facilitate the review.

Thank you for your time and consideration,

The Editorial Office


review.frontiersin.org/review/1286484/16/1484704/#tab/History

ABOUT JOURNALS RESEARCH TOPICS ARTICLES SUBMIT

History | Editor Active | Reviewer 1 Finalized | Reviewer 2 Finalized | A I R A

Handling Editor: Alfrendo Satyanaga
Received date: 31 Aug 2023
Editorial assignment start date: 01 Sep 2023
Independent review start date: 03 Sep 2023
Review finalized date: 13 Sep 2023

You can post and reply to comments about the manuscript here. Note that the reviewers can also read these comments.

Re-submit manuscript

Revision request

Editorial Office: Frontiers in Built Environment Editorial Office | 13 Sep 2023 | 10:12 #1

Dear Author(s),

Please consider any outstanding revision requests from all reviewers, including the reviewers who recommended rejection (if any).

You can respond to the comments in this thread and resubmit the revised manuscript. We encourage you to submit your revised manuscript with tracked changes to facilitate the review.

Thank you for your time and consideration,
The Editorial Office

Dear Dr Tallar,

A new review report has been submitted by a Reviewer 1. Once the other Reviewer(s) have submitted their comments, you will be granted access to the reports in the review forum, so that you can begin your revisions. Please be ready to respond and revise your manuscript promptly when they do.

Please click here to access this manuscript directly:

http://review.frontiersin.org/review/1286484/0/0

Manuscript title: The Conceptual Design of Stream Island Index (SII): Template for Physical Habitat Complexity Assessment in Stream Restoration Projects

Manuscript ID: 1286484

Authors: Robby Yussac Tallar

Journal: Frontiers in Built Environment, section Sustainable Design and Construction

Article type: Original Research

Submitted on: 31 Aug 2023

Best regards,

Your Frontiers in Built Environment Team,

Frontiers | Editorial Office - Collaborative Peer Review Team

www.frontiersin.org

Avenue du Tribunal Fédéral 34

1005 Lausanne Switzerland

****

Independent Review Report, Reviewer 1

EVALUATION

Please list your revision requests for the authors and provide your detailed comments, including highlighting limitations and strengths of the study and evaluating the validity of the methods, results, and data interpretation. If you have additional comments based on Q2 and Q3 you can add them as well.

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Check List

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Yes

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c. Are the statistical methods valid and correctly applied? (e.g. sample size, choice of test)

Yes

d. Is a statistician required to evaluate this study?

No

e. Are the methods sufficiently documented to allow replication studies?

Yes

QUALITY ASSESSMENT:

Rigor

4

Quality of the writing

4

Overall quality of the content

4

Interest to a general audience

5

ABOUT JOURNALS RESEARCH TOPICS ARTICLES SUBMIT

History	Editor Active	Reviewer 1 Finalized	Reviewer 2 Finalized	AIRA

Reviewer 1
Independent review report submitted: 13 Sep 2023

Initial recommendation to the Editor: Minor revision is required

---

The review report is displayed here. As the Reviewer endorsed publication of this manuscript, discussions are now closed.

Re-submit manuscript

EVALUATION

Q 1 **Please list your revision requests for the authors and provide your detailed comments, including highlighting limitations and strengths of the study and evaluating the validity of the methods, results, and data interpretation. If you have additional comments based on Q2 and Q3 you can add them as well.**

Reviewer 1 | 13 Sep 2023 | 10:12 #1

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https://www.frontiersin.org/submission/submit

ABOUT JOURNALS RESEARCH TOPICS ARTICLES SUBMIT

Q 2 Check List

Reviewer 1 | 13 Sep 2023 | 10:12 #1

a. Is the quality of the figures and tables satisfactory?
- Yes

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- Yes

QUALITY ASSESSMENT

Q 3	Rigor	4/5
Q 4	Quality of the writing	4/5
Q 5	Overall quality of the content	4/5
Q 6	Interest to a general audience	5/5

Dear Dr Tallar,

A new review report has been submitted by a Reviewer 2. Once the other Reviewer(s) have submitted their comments, you will be granted access to the reports in the review forum, so that you can begin your revisions. Please be ready to respond and revise your manuscript promptly when they do.

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Journal: Frontiers in Built Environment, section Sustainable Design and Construction
Article type: Original Research
Submitted on: 31 Aug 2023

Best regards,
Your Frontiers in Built Environment Team,

Frontiers | Editorial Office - Collaborative Peer Review Team
www.frontiersin.org
Avenue du Tribunal Fédéral 34
1005 Lausanne Switzerland

****

Independent Review Report, Reviewer 2
EVALUATION
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QUALITY ASSESSMENT:
Rigor
5
Quality of the writing
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Overall quality of the content
5

Interest to a general audience

4

ABOUT JOURNALS RESEARCH TOPICS ARTICLES SUBMIT

History	Editor Active	Reviewer 1 Finalized	Reviewer 2 Finalized	A I R A

Reviewer 2

Independent review report submitted: 12 Sep 2023

Initial recommendation to the Editor: Minor revision is required

The review report is displayed here. As the Reviewer endorsed publication of this manuscript, discussions are now closed.

Re-submit manuscript

EVALUATION

Q 1 **Please list your revision requests for the authors and provide your detailed comments, including highlighting limitations and strengths of the study and evaluating the validity of the methods, results, and data interpretation. If you have additional comments based on Q2 and Q3 you can add them as well.**

Reviewer 2 | 12 Sep 2023 | 16:37 #1

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Review supporting file - 577681

ABOUT JOURNALS RESEARCH TOPICS ARTICLES SUBMIT

Q 2 Check List

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QUALITY ASSESSMENT

Q 3 Rigor

Q 4 Quality of the writing

Q 5 Overall quality of the content

Q 6 Interest to a general audience

RESPONSE TO EDITOR

Dear Editor,

Thank you for your letter regarding our manuscript, titled "The Conceptual Design of Stream Island Index (SII): Template for Physical Habitat Complexity Assessment in Stream Restoration Projects". I appreciate your Reviewer 1 and 2 for the feedback and suggestions. I have also carefully addressed each of the reviewers' comments in the attached response document, and I am pleased to resubmit our manuscript after having the revisions.

I believe that those revisions have improved the quality of my manuscript and made it more suitable for publication in your journal.

I hope that you will consider it for publication in your journal. Thank you for your time and consideration.

Sincerely,

Robby Yussac Tallar

Dear Dr Tallar,

A new review report has been submitted by a Reviewer 1. Once the other Reviewer(s) have submitted their comments, you will be granted access to the reports in the review forum, so that you can begin your revisions. Please be ready to respond and revise your manuscript promptly when they do.

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Authors: Robby Yussac Tallar
Journal: Frontiers in Built Environment, section Sustainable Design and Construction
Article type: Original Research
Submitted on: 31 Aug 2023

Best regards,
Your Frontiers in Built Environment Team,

Frontiers | Editorial Office - Collaborative Peer Review Team
www.frontiersin.org
Avenue du Tribunal Fédéral 34
1005 Lausanne Switzerland

For technical issues please contact our IT Helpdesk (support@frontiersin.org) or visit our Frontiers Help Center (helpcenter.frontiersin.org)

****

Independent Review Report, Reviewer 1
EVALUATION
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QUALITY ASSESSMENT:
Rigor
4
Quality of the writing
4
Overall quality of the content
4
Interest to a general audience
5

Summary

No	Comments from reviewer	Reply from author	Line
1	The manuscript titled "The Conceptual Design of Stream Island Index (SII): Template for Physical Habitat Complexity Assessment in Stream Restoration Projects". The topic of Stream Island is interesting. However, there is still some parts need to be improved from the manuscript.	Thank you very much for your feedback. The author agree that more improvement is needed to support the paper. The author already revised several parts from the manuscript. The author believe that the manuscript is appropriate for this journal.	1-2; 18-20; 23-25; 28-32; 126-127; 139-140; 159-167; 243-260;
2	The objective needs to be stated more clearly in the abstract and introduction part.	Thank you for your feedback. The author agree that the objective of our research could be stated more clearly in the abstract and introduction. In the abstract, the author has revised the sentence to state the objective more directly as well as the introduction part. The objective of the study is to develop a conceptual design of Stream Island Index (SII) as a template for physical habitat complexity assessment in stream restoration projects.	18-20; 66-68

3	Typo and grammatical errors need to be corrected such as table numbering on page 7. It should be Table 1 instead of Table 3 as shown in the manuscript	Thank you for pointing out the typo in the table numbering on page 7. The author has corrected this error and the table is now labeled as Table 1. The author has also carefully proofread the entire manuscript again to correct any other typos or grammatical errors. Thank you for your help in improving the manuscript.	139
4	Resolution of some figures needs to be improved	Thank you for your feedback. The author agree that the resolution of some of the figures in the manuscript needs to be improved. The author has redrawn for figures. The author has checked each figure for any pixilation or blurring. If the author found any issues, the author have made the necessary adjustments. The author has also made sure that all of the figures are the correct size for publication. The author has attached a revised version of the manuscript with the improved figures.	105-106; 123-124; 139-140
5	Permission to use Figures from other studies needs to be checked especially Fig 1 and 3	Thank you very much for the suggestions. Due to the limitation of information, so the author change the design of Figure 1 and 3, so the Figures are original from the other studies.	105-106; 139-140
6	Conclusions need to change to address the objective of the study	Thank you for your suggestion. The author followed the suggestion. Conclusions already added some sentences to address the objective of study. The revised and added sentences as follow: In conclusion, the conceptual design of the Stream Island Index (SII) is comprehensive methodology development as a template for physical habitat complexity assessment in stream restoration projects. The SII combines the measures of selected physical habitat quality parameters to produce a single dimensionless number, and a novel approach to communicate information on stream island quality status to the public and related policy makers. It	239-253

		also has the potential to be a valuable tool for stream restoration practitioners. The SII can be used to set specific goals for restoration projects, such as increasing the number of islands in a stream or improving the physical habitat diversity. The SII can be used to track progress over time to see how well restoration projects are meeting their goals. Moreover, it also can be used to compare the success of different restoration approaches, such as using different types of in-stream structures or different planting strategies. Finally, the SII also can be used to communicate the value of stream restoration to the public by explaining how the index works and how it can be used to assess the quality of stream habitat. Therefore, the SII is a promising new tool for stream restoration practitioners, and it has the potential to make a significant contribution to improving the success of stream restoration projects.	

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Manuscript ID: 1286484
Authors: Robby Yussac Tallar
Journal: Frontiers in Built Environment, section Sustainable Design and Construction
Article type: Original Research
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Independent Review Report, Reviewer 2
EVALUATION
Please list your revision requests for the authors and provide your detailed comments, including highlighting limitations and strengths of the study and evaluating the validity of the methods, results, and data interpretation. If you have additional comments based on Q2 and Q3 you can add them as well.
The Authors proposed a methodology development, called Stream Island Index (SII) as a template for physical habitat complexity assessment in stream restoration projects. Specific purposes included: to examine the stream island conceptual models; (b) to develop obvious and comprehensive explanations of the stream island development by considering attributes from the geomorphology, hydraulics and ecological perspective. The works are comprehensive and original. Some revisions are required to improve the quality of manuscripts.

1. Revised the title from "The Conceptual Design of Stream Island Index (SI 1 I): Template for Physical Habitat Complexity Assessment in Stream Restoration Projects" into "The Conceptual Design of Stream Island Index for Physical Habitat Complexity Assessment in Stream Restoration Projects"
2. Provide one sentence describing methodology of the research in the abstract
3. Authors should provide additional recent literatures especially from 2015 until 2023
4. Provide scale in Figure 1 and improve resolution of Figure 1. Was permission to extract this figure from the original author has been obtained?
5. Provide scale in Figure 2 and improve resolution of Figure 2.
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7. Provide scale in Figure 3 and improve resolution of Figure 3. Was permission to extract this figure from the original author has been obtained?
8. Provide theoretical background on the development of Equation 1. Reference or derivation of equation?
9. Analytical Hierarchy Process (AHP) was mentioned in Line 168, but there was not literature review or theoretical background for this method. Please provide brief explanation about this method.
10. check Typo and Gramatical Error in the manuscript.

Check List
a. Is the quality of the figures and tables satisfactory?
Yes
b. Does the reference list cover the relevant literature adequately and in an unbiased manner?
Yes
c. Are the statistical methods valid and correctly applied? (e.g. sample size, choice of test)
Yes
d. Is a statistician required to evaluate this study?
No
e. Are the methods sufficiently documented to allow replication studies?
Yes
QUALITY ASSESSMENT:
Rigor
5
Quality of the writing
4
Overall quality of the content
5

Interest to a general audience
4

No	Comments from reviewer	Reply from author	Line
1	Revised the title from "The Conceptual Design of Stream Island Index (SI 1 I): Template for Physical Habitat Complexity Assessment in Stream Restoration Projects" into "The Conceptual Design of Stream Island Index for Physical Habitat Complexity Assessment in Stream Restoration Projects"	Thank you very much for the input. The author revise the title following the recommendation from the reviewer. Revised sentence: The new title is "The Conceptual Design of Stream Island Index for Physical Habitat Complexity Assessment in Stream Restoration Projects"	1-2
2	Provide one sentence describing methodology of the research in the abstract	Thank you very much for the suggestion. The author added one sentence describing methodology of the research in the abstract following the suggestion from reviewer. Revised sentence: This study used AHP method as follows screening and selecting attributes, transforming and developing sub-indices, assignment of weights, and formulating an index.	23-25
3	Authors should provide additional recent literatures especially from 2015 until 2023	Thank you for the suggestion. The author add some recent literatures as follow: • Rubin Z, Kondolf GM, Rios-Touma B. (2017). *Evaluating Stream Restoration Projects: What Do We Learn from Monitoring?* Water 9(3):174. • Kaushal, S. S., Fork, M. L., Hawley, R. J., Hopkins, K. G., Ríos-Touma, B., & Roy, A. H. (2023). Stream restoration milestones: monitoring scales determine successes and failures. *Urban Ecosystems*, 1-12. • Herrington, C. S., & Horndeski, K. (2023). *Is urban stream*	284-287; 297-298; 307-308

		- *restoration really a wicked problem?*. Urban Ecosystems, 26(2), 479-491. - Verdonschot, P. F. M., & Verdonschot, R. C. M. (2023). The role of stream restoration in enhancing ecosystem services. Hydrobiologia, 850(12-13), 2537-2562.	
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5	Provide scale in Figure 2 and improve resolution of Figure 2.	Thank you very much for the input. The author provide scale in Figure 2 and also improve resolution on Figure 2.	
6	Check Table numbering. Suddenly there is Table 3, without Tables 1 and 2.	Thank you for reminding. The author revised the Table numbering.	
7	Provide scale in Figure 3 and improve resolution of Figure 3. Was permission to extract this figure from the original author has been obtained?	Thank you for your feedback. The author provide scale in Figure 3 and also improve resolution on Figure 3. Regarding the permission, due to the limitation of information, the author decided to change the design of Figure, so that the Figure is the original one.	
8	Provide theoretical background on the development of Equation 1. Reference or derivation of equation?	Thank you for the input. The author provides theoretical background on the development of Equation 1. Based on previous studies, in order to develop an index, first it is important to identify the concept or variable to measure and then the selected variables should be included in the developing index. Then, assign scores to each variables. The scores should be based on the relative importance of each variables to the concept or variable. It means the level or weight of importance should be defined. Next step is combine the scores of the individual variables to create the index. There are a number of different ways to do this. According to previous	

		research with title "An Integrated Indicator Based on Basin Hydrology, Environment, Life, and Policy: The Watershed Sustainability Index" (Chavez and Alipaz, 2006), one common approach is to take the average of the scores of the individual variables.	
9	Analytical Hierarchy Process (AHP) was mentioned in Line 168, but there was not literature review or theoretical background for this method. Please provide brief explanation about this method.	Thank you for your feedback. The author agree that the Analytical Hierarchy Process (AHP) was not adequately explained in the manuscript. The author has added a brief explanation of this method to the introduction section, as follows: The Analytical Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It was developed by Thomas L. Saaty in the 1970s and has been refined since then. AHP involves breaking down a complex decision into a hierarchy of criteria and subcriteria. The decision-maker then compares the relative importance of each criterion and subcriterion using a pairwise comparison matrix. The AHP software then calculates the weighted importance of each criterion and subcriterion, as well as the overall ranking of the alternatives. AHP is a powerful tool for decision-making, but it is important to use it carefully and to be aware of its limitations. One limitation is that AHP is sensitive to the pairwise comparisons made by the decision-maker. If the decision-maker is biased or does not have a good understanding of the problem, the results of the AHP analysis may be inaccurate. Another limitation is that AHP is a complex method and can be difficult to use for large problems. However, there are a number of software packages available that can assist with the AHP analysis.	

		The author believe that this explanation will help readers to understand how the author used AHP in this study and to interpret the results of the analysis. Thank you for your help in improving the manuscript.	
10	Check Typo and Gramatical Error in the manuscript	Thank you for pointing out the typo and grammatical error. The author has corrected this error. The author has also carefully proofread the entire manuscript again to correct any other typos or grammatical errors. Thank you for your help in improving the manuscript.	

The Conceptual Design of Stream Island Index (SII): Template for Physical Habitat Complexity Assessment in Stream Restoration Projects

The Conceptual Design of Stream Island Index for Physical Habitat Complexity Assessment in Stream Restoration Projects

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Abstract

Most literatures on geomorphology, hydraulics or stream ecology contained no mention or less description about stream island, the process, the development or the ecological advantages provided. Due to a lack of information, research and related data, there were no stream island indexes available for indicating the stream island status. Motivated by the fact, this paper proposed a comprehensive methodology development, called the objective of this study is to develop a conceptual design of Stream Island Index (SII) as a template for physical habitat complexity assessment in stream restoration projects. Specific purposes included: (a) to examine the stream island conceptual models; (b) to develop obvious and comprehensive explanations of the stream island development by considering attributes from the geomorphology, hydraulics and ecological perspective. This study used AHP method as follows screening and selecting attributes, transforming and developing sub-indices, assignment of weights, and formulating an index. The conclusion is a Stream Island Index (SII) combines the measures of selected physical habitat quality indicators to produce a single dimensionless number, and a novel approach to communicate information on stream island quality status to the public and related policy makers. It seems essential that a serious attempt be developed to design a system that can identify the overall stream island condition. Once a generalized stream island system is set up as a controlling framework, supplementary indexes for specific purposes and location can be added. Therefore, the SII is a promising new tool for stream restoration practitioners, and it has the potential to make a significant contribution to improving the success of stream restoration projects.

Keywords: Index; Habitat Characteristics; Stream Island; Stream Restoration Projects

Introduction

Natural streams are dynamic and physically and biologically very complex (Tockner & Stanford, 2002). The habitat complexity is not only the physical characteristics but also the uses of the streams themselves. Many experts such as river engineers, geomorphologists, civil engineers, and ecologists might well have a similar opinion especially when it is recognized how variable and complex a river with all living beings within can be through time and from reach to reach of the river. Therefore, it is still challenging to discover comprehensive results without considering all the stream variables. Stream island is one of the physical habitat features in streams. In the past, the role of stream islands has been almost totally ignored by civil engineers due to lack of understanding of the geomorphology, hydraulics, and ecological functions of stream island within. In stream restoration projects, the existence of stream island often did not consider as an important variable or major influence in many cases study. Many researchers generally only focused on the permanent islands such as continental fragments, exposed lands in lakes, coral reefs, or barrier islands, few have concept design or further detailed research about the development of stream island in streams. Most literature on geomorphology, hydraulics or stream ecology also contained no mention or less description about stream island in streams, the process, the development, or the further ecological advantages provided. A lot of previous research also only concentrated with the large and braided river such as Tagliamento River, Italy (Gurnell et. al., 2001; Francis et. al, 2009; Comiti et. al., 2011). None or a few research explored about concept design of the island in the stream itself considering the context of the development of physical habitat complexity within.

On the other hand, physical habitat complexity plays an important role in community structure in natural streams along with a variety of geomorphology, hydraulics, and ecological processes (Schluter and Ricklefs, 1993; Rahbek and Graves, 2001). Physical habitat complexity within natural streams should be viewed as planform patterns provide the initial physical habitat template. Heterogeneity and complexity of physical habitat structure were governed by geomorphic, hydraulics, and ecological form and processes associated with a state of dynamic equilibrium. Therefore, it can be expected that changes in geomorphic, hydraulics, and ecological form and processes at the planform scale can be quantified through measurements and assessments. Hence, in the traditional physical habitat complexity assessment in stream restoration projects assessments is often focused geomorphology attributes only. Motivated by the fact, this paper proposed a comprehensive methodology development, called Stream Island Index (SII) as a template for physical habitat complexity assessment in stream restoration projects. Specific purposes included: (a) to examine the stream island conceptual models; (b) to develop obvious and comprehensive explanations of the stream island development by considering attributes from the geomorphology, hydraulics and ecological attributes.

Material and methods

Stream islands versus Stream bars

It is important to understand how stream islands and stream bars are different. Natural streams constantly exhibit distinctive behavior and patterning in their properties from a geomorphic standpoint. Studying the stream features also always dependent with the river morphology and time. Over time by time, bed topography is influenced by both local and systematic variation in sediment supply and the stream power so that it always changes. These changes affect the diversity and complexity of stream features including stream bars and stream islands. Stream bar is defined following the American Society of Civil Engineers (ASCE) Task Force (1966) as a bedform with length of the same order of magnitude as the channel width and height comparable to the depth of the generating flow (Rice et. al., 2009). As a result, it may be stated that bars are sediment storage regions within streams as well as energy dissipaters that aid in stream configuration stabilization (Church and Jones, 1982). Stream bars are fundamental geomorphic components that should be exposed, solitary, in-channel entities with simple depositional histories regulated by local flow and sediment supply circumstances (Smith, 1974). Stream bars have two key hydraulic phenomena: flow expansion at the bar head generates an upstream diffluence zone and converges downstream at the confluence. Stream bars travel downstream or expand and migrate laterally in steady-state flow, as in meandering streams.

Stream island differs slightly from stream bar. Although the physical appearance of stream island is similar to that of stream bar, there are several aspects in stream island that the stream bar does not have. Stream bars can generate stream islands with some processes within over time. Combined process and fulfilled some requirements of the stream bar to become stream island can be seen in Figure 1. A simple model of stream bar to island development was proposed to explain the process and mechanisms involved. Since the stream produces the stream bars, and the stream bars develop the stream islands, there are two major phases. During the first phase, the stream frequently runs with transporting sediments and deposits sediment until a limitation height is reached. During phase two, the material that deposited the bar might collect over time, causing the stream bar to become stable, dense, compacted, and variable. We categorized this phase as an initial stream island development. The material sediment can be varied in shape and diameter such as gravels or sands. However, bars should not be thought of as single morphological entities. They often exist as the result of a complex erosional and depositional chronology linked to the nature of the flood series following stream bar initiation.

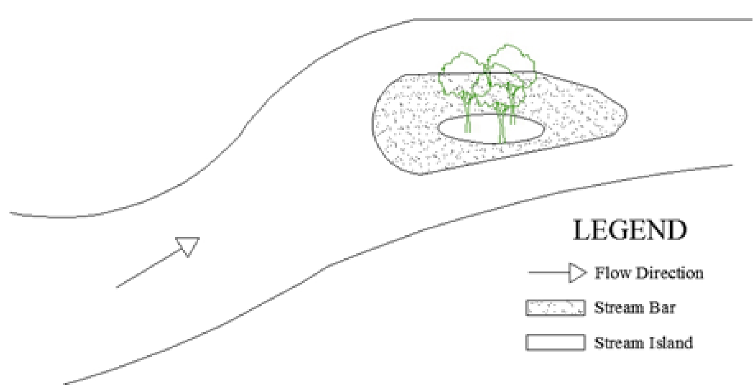

Fig. 1. A schematic of typical stream bar and island development

(Modified from: Cooperman and Brewer, 2005)

The conceptual framework for stream island development

The majority of studies have documented the formation of stream islands in relation to their specific study site; for example, Gurnell et al. (2001) investigated the influence of riparian vegetation, sediment type, and hydrologic regime on island formation in the Fiume Tagliamento, Italy. They created a conceptual model for island formation in the research area and discovered that islands arise by channel avulsion or vegetation on exposed gravel bars. Popov (1962) defined the types of island modifications that he noticed in River Ob, Russia. Meanwhile, Osterkamp (1998) examined all of the processes that might be linked with islands in more detail. He proposed categorizing islands into at least eight groups depending on their development process, as in the preceding explanations. Cooperman and Brewer (2005) predicted that fluvial dynamics influence the maturation of stream islands, and that patterns of vegetation distribution would correlate to patterns of island growth (Figure 2). In general, stream island formation processes consisted of 9 categories: avulsion, gradual erosion, lateral shifts, bar/riffle stabilization, structural features, flood deposits, lee deposits, mass movement and reservoir installation.

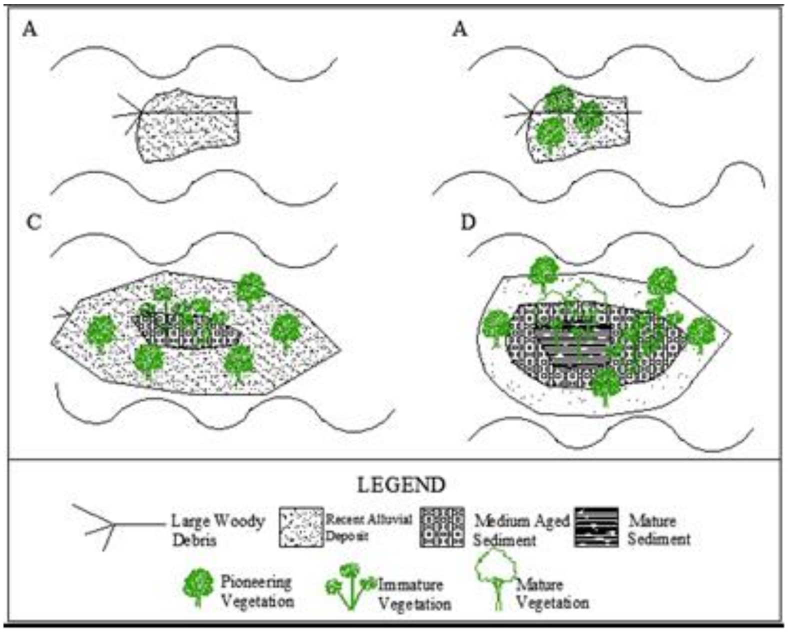

Fig. 2. ~~Two types hypothesized process concept of stream island development~~ The step-by-step process of concept design of stream island development

The conceptual framework for stream island development was designed the standard in order to reach specific purpose such as stream health, stream restoration, etc. The ecological variables in the vegetation development and microinvertebrates indicators should be counted in stream island development. The degree of vegetation development on stream island is likely to be related to the amount of time the surface has been exposed above the seasonal low-water level, the position of water table, the physical character of sediments and their stability and the types of vegetation available for colonization. Depending on these factors, newly formed stream island are progressively vegetated as they accrete vertically and laterally and it thus becomes difficult to define where an initial stream island becomes a complex stream island. There are some terms in habitat types of the stream island introduced based on literature reviews (Table 1 and Figure 3).

Table ~~3~~1. Habitat of Stream Island

Habitat Types	Definition
Island Head	~~Upstream end of a stream island. Surface substrate is usually coarse like gravels and cobbles. The natural event usually erosional due to the high velocity, but can be depositional due to a back eddy.~~ The starting point of an island within a stream. Typically, the surface material is rough, such as gravel and pebbles. Typically, this phenomenon is caused by erosion caused by high speed, although it can result in deposition due to a reverse current.
Island Tail	~~Downstream end of a stream island. Surface substrate consists of smaller cobbles and gravels. The flow velocity is usually lower than upstream end of a stream island.~~ The terminal point of an island located along the course of a river. The uppermost layer of the ground is composed of small-sized rocks and pebbles. Typically, the flow velocity or current is slower at the downstream side of a stream island compared to its upstream side.
Island Edge	~~Any length of island edge not occurring at the head or tail of an island but at side of island that is oriented parallel to the flow and subject to constant and consistent flow forces. A range of velocities and substrate types is vary in between.~~ Any length of island edge that does not occur at the head or tail of an island but on a side of the island that is parallel to the flow and subject to steady and consistent flow forces. There is a wide variety of velocities and substrate kinds in between.
Inner Island	~~Area located in the interior, consists of permanent vegetation, the highest elevation and mostly dry area.~~ The central area of island that has permanent vegetation, the highest elevation, and is usually dry.
Transitional Area	Area between inner and outside island.
Outside Island	~~Area bounded by flowing water. Small vegetation growth in this area. Bank slope is relatively flat and the substrate is usually embedded sand and/or cobble.~~

	A zone bordered by moving water. This location has sparse vegetation growth. The bank slope is usually rather level, with embedded sand and/or pebbles as the substrate.

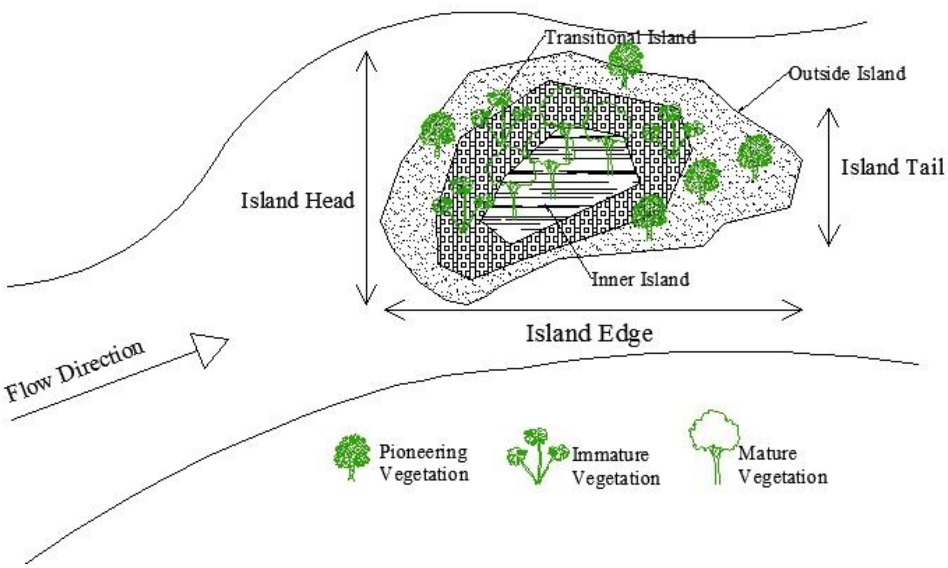

Fig. 3. A schematic of habitat island types ~~(Modified from: Cooperman and Brewer, 2005)~~

Results and Discussion

This study proposes a conceptual framework for developing stream island evaluation index towards sustainable stream restoration project. It seems essential that a serious attempt be developed to design a system that can identify the overall stream island condition. Once a generalized stream island system is set up as a controlling framework, supplementary indexes for specific purposes and location can be added.

A Proposed Methodology for Stream Island Index (SII)

This study provided a comprehensive methodological process for developing a conceptual framework of the Stream Island Index (SII) (Figure 4 and Table 2). The purpose should be defined first. In constructing a conceptual framework, this study emphasized the ecological aspect in addition to the hydraulics and geomorphology attributes. In the framework of a design and method study, it appears necessary to create and validate an index for measuring the parameters involved. A considerable effort was made to develop an index system capable of measuring the overall status of stream island. ~~After establishing a conceptual framework system, supplementary indexes for specific purposes and locations can be added.~~ In order to develop an index, first it is important to identify the concept or variable to measure and then the selected variables should be included in the developing index. Then, assign scores to each variables. The scores should be based on the relative importance of each variables to the concept or variable. It means the level or weight of importance should be defined. Next step is combine the scores of the individual variables to create the index. Detail steps to create an index can be seen on Table 2. According to previous study (Chavez and Alipaz, 2006), one common approach is to take the average of the scores of the individual variables. Therefore, in this ~~Continue to the~~ offered analysis, an index formed by attributes meeting the above criteria could be universally applied, which would significantly increase their usefulness in establishing the development of Stream Islands Index (SII) in a matrix scheme. Numericaly, the SII can therefore be represented as:

$$\mathrm{SII} = \sum_{i=1}^{n} w_i C_i \qquad (1)$$

Where w_i was the average weight factor for the i^{th} parameter, and C_i was the standardized sub-index for the i^{th} parameter. Each quality value was then multiplied by an average weight factor, to take into account the relative contribution of each variable to the overall index.

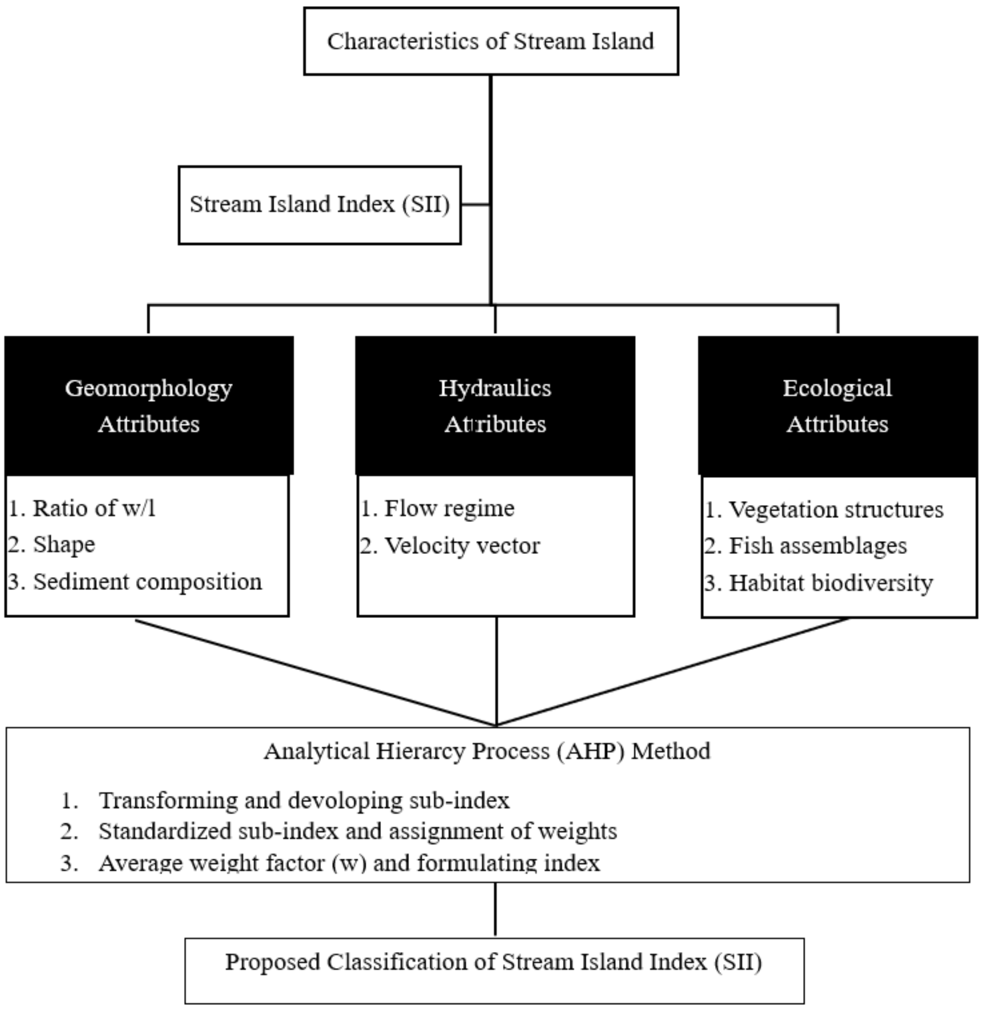

Fig. 4. A conceptual framework of the Stream Island Index (SII)

Table 2. Methods for developing SII

No.	Stages	Spatial data analysis	Interviews with experts	Field survey measurements

1	Screening and selecting attributes	●	●	●
2	Transforming and developing sub-indices	●		●
3	Assignment of weights	●	●	
4	Formulating an index	●		

This study also used the Analytical Hierarchy Process (AHP) method. This method is a structured mathematics and psychology technique for organizing and analyzing complex decisions that was developed by Thomas L. Saaty in the 1970s and has been refined since then. AHP involves breaking down a complex decision into a hierarchy of criteria and subcriteria. The decision-maker then compares the relative importance of each criterion and subcriterion using a pairwise comparison matrix. The AHP software then calculates the weighted importance of each criterion and subcriterion, as well as the overall ranking of the alternatives. AHP is a powerful tool for decision-making, but it is important to use it carefully and to be aware of its limitations. One limitation is that AHP is sensitive to the pairwise comparisons made by the decision-maker. If the decision-maker is biased or does not have a good understanding of the problem, the results of the AHP analysis may be inaccurate.

In context of Analytical Hierarchy Process (AHP) process, there are several stages for developing SII (Table 2). First, spatial data should be performed by spatial analysis that reveal the geometric or geographic properties of data. Spatial data could use a computational model such as Geographic Information System (GIS)-based model. This study proposed the rapid advancement of ArcGIS combined with Google-Earth software in spatial analyses of environmental stream island and habitat data triggered the need for change in methods of field survey measurements. Next method is interviews with experts in order to process the Analytical Hierarchy Process (AHP) method. Expert judgments have often been used to acquire criteria weights when there was a lack of the required data (Reza et al., 2013) and used the various softwares such as Expert Choice 11.0 to analyze multi-criterion decision-making problems based on the AHP approach. The experts thus evaluated the various criteria and alternatives using a numerical scale, as shown in Table 3.

Table 3. Ratio scale used with note 2, 4, 6, and 8 are the mid-values between two adjoining ones

Ratio Scale	Comparison between two factors
1	Equally important
3	Moderately important
5	Strongly important
7	Very strongly important
9	Extremely important

Concerning field survey measurements especially in fish assemblages indicators, sampling fish by using electrofishing device is the appropriate method. This method identifies specific fish habitat use in streams. Moreover, the snorkling method also can be used in clear stream condition with some constraints such as the obsterver’s ability to identify species and characterized by spatial and temporal heterogeneity across various scales.

The understandings of SII in stream restoration projects

Civil engineers, environmental engineers, stream ecologists, aquatic biologists and other stakeholders all embark on stream restoration projects from a disiplinary perspective. However, lack of integration among these various practitioners has resulted in limited project success in many cases. Stream island in restoration projects has important role since ecological failures has often occured from engineering designs that ignoring the existance of it. Therefore, to avoid such effects, it is necessary to ensure that geomorphology, hydraulics and ecological attributes from stream island are mutually considered within the stream restoration design process. The proposed design framework to stream restoration projects, as conceptualized by naturalization, applies fluvial geomorphology, hydraulic engineering, and stream ecology to provide a more robust design approach to design in human-dominated stream management, and has greater potential of success to achieve ecosystem stability. Integration of three attributes requires a three-dimentional view of stream island morphology and hydraulics, along with ecological patterns that express habitat complexity with biological needs. From a new view of stream island habitat and its analysis, ecological criteria will be better integrated into stream restoration projects for application by water resource proffesionals.

Many previous studies has focused on fluvial systems that maintain stream islands with addressing the needs of understanding in aquatic ecology ecosystem functioning (e.g. Osterkamp, 1998; Edwards et al., 1999; Gurnell and Petts, 2002; Tockner et. al., 2003; Karaus et al., 2005; Francis et. al., 2008). Recent research has also highlighted the important role of feedbacks between organisms and physical processes in determining the spatial structure and dynamics of ecosystems, both terrestrial and aquatic (Francis et. al., 2008). One of the results is the aggregating of sediment and hydraulic roughness on the gravel bars, created the stabilization of the initial stream island. For some cases, the stream island formed by the gravel bar and the deposition of large woody debris (LWD) above. Organic detritus, fine sediments and organisms (e.g. plant propagules, fish, invertebrates) mostly are trapped in and around the deposited LWD or vegetation (e.g. Karaus et al., 2005).

Conclusion

~~This study A Stream Island Index (SII) combines the measures of selected physical habitat quality parameters to produce a single dimensionless number, and a novel approach to communicate information on stream island quality status to the public and related policy makers.~~

In conclusion, the conceptual design of the Stream Island Index (SII) is comprehensive methodology development as a template for physical habitat complexity assessment in stream restoration projects. The SII combines the measures of selected physical habitat quality parameters to produce a single dimensionless number, and a novel approach to communicate information on stream island quality status to the public and related policy makers. It also has the potential to be a valuable tool for stream restoration practitioners. The SII can be used to set specific goals for restoration projects, such as increasing the number of islands in a stream or improving the physical habitat diversity. The SII can be used to track progress over time to see how well restoration projects are meeting their goals. Moreover, it also can be used to compare the success of different restoration approaches, such as using different types of in-stream structures or different planting strategies. Finally, the SII also can be used to communicate the value of stream restoration to the public by explaining how the index works and how it can be used to assess the quality of stream habitat. Therefore, the SII is a promising new tool for stream restoration practitioners, and it has the potential to make a significant contribution to improving the success of stream restoration projects.

For future works, there are several potential considerations for the development of the Stream Island Index in habitat assessment such as the expansion of spatial coverage of Stream Island Index by recommendations from stakeholders of land management (federal agencies, state, tribal, and private lands). It also will provide a more comprehensive assessment of physical habitat complexity in stream restoration projects. However, it may be beneficial to develop regional-specific templates within the Stream Island Index framework. These regional-specific templates would take into account the unique characteristics and dynamics of different geographic regions.

Acknowledgements

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The conceptual design of a stream island index for physical habitat complexity assessment in stream restoration projects

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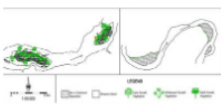

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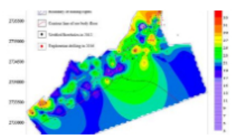

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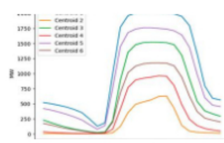

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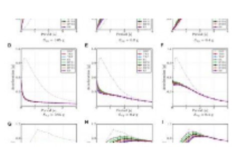

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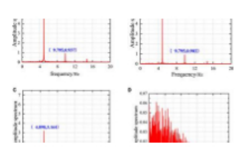

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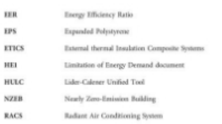

EER	Energy Efficiency Ratio
EPS	Expanded Polystyrene
ETICS	External thermal Insulation Composite Systems
HEI	Limitation of Energy Demand document
HULC	Lider-Calener Unified Tool
NZEB	Nearly Zero-Emission Building
RACS	Radiant Air Conditioning System

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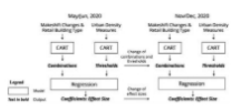

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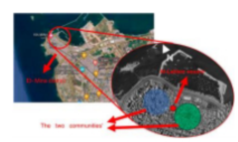

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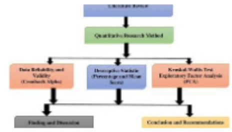

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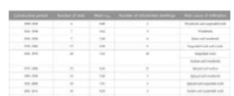

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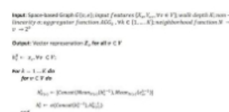

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The conceptual design of a stream island index for physical habitat complexity assessment in stream restoration projects

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Most literature on geomorphology, hydraulics, or stream ecology contained either no mention or a brief description of stream islands, the process, the development, or the ecological advantages provided. Due to a lack of information, research, and related data, there were no stream island indexes available to indicate the stream island status. Motivated by this fact, the objective of this study is to develop a conceptual design for a Stream Island Index (SII) as a template for physical habitat complexity assessment in stream restoration projects. Specific purposes included: 1) to examine stream island conceptual models; 2) to develop obvious and comprehensive explanations for stream island development by considering attributes from the geomorphic, hydraulic, and ecological perspectives. This study used the AHP method for screening and selecting attributes, transforming and developing sub-indices, assigning weights, and formulating an index. The conclusion is an SII that combines the measures of selected physical habitat quality indicators to produce a single dimensionless number, and a novel approach to communicate information on stream island quality status to the public and related policymakers. It seems essential that a serious attempt be developed to design a system that can identify the overall stream island condition. Once a generalized stream island system is set up as a controlling framework, supplementary indexes for specific purposes and locations can be added. Therefore, the SII is a promising new tool for stream restoration practitioners, and it has the potential to make a significant contribution to improving the success of stream restoration projects.

KEYWORDS
index, habitat characteristics, stream island, stream restoration projects, AHP

Introduction

Natural streams are dynamic and physically and biologically very complex (Tockner and Stanford, 2002). The habitat complexity is not only the physical characteristics but also the uses of the streams themselves. Many experts such as river engineers, geomorphologists, civil engineers, and ecologists might well have a similar opinion especially when it is recognized how variable and complex a river with all living beings within can be through time and from reach to reach of the river. Therefore, it is still challenging to discover comprehensive results without considering all the stream variables. Stream islands are one of the physical habitat features in streams. In the past, the role of stream islands has been almost totally ignored by civil engineers due to a lack of understanding of the geomorphology, hydraulics, and

ecological functions of stream islands. In stream restoration projects, the existence of stream islands often was not considered as an important variable or major influence in many case studies. Many researchers generally only focused on permanent islands such as continental fragments, exposed lands in lakes, coral reefs, or barrier islands, and few have concept designs or further detailed research about the development of stream islands in streams. Most literature on geomorphology, hydraulics, or stream ecology also contained either no mention or a brief description of stream islands in streams, the process, the development, or the further ecological advantages provided. A lot of previous research also only concentrated on large and braided rivers such as the Tagliamento River in Italy (Gurnell et al., 2001; Francis et al., 2009; Comiti and Da Canal, 2011). Few research studies have explored a concept design of the island in the stream itself considering the context of the development of physical habitat complexity within.

Physical habitat complexity plays an important role in community structure in natural streams along with a variety of geomorphology, hydraulics, and ecological processes (Kollmann et al., 1999; Wohl et al., 2005; Rubin et al., 2017; Herrington and Horndeski, 2023; Kaushal et al., 2023; Verdonschot and Verdonschot, 2023). Physical habitat complexity within natural streams should be viewed as planform patterns that provide the initial physical habitat template. The heterogeneity and complexity of physical habitat structures are governed by geomorphic, hydraulic, and ecological forms and processes associated with a state of dynamic equilibrium. Therefore, it can be expected that changes in geomorphic, hydraulic, and ecological forms and processes at the planform scale can be quantified through measurements and assessments. Hence, the traditional physical habitat complexity assessment in stream restoration project assessments is often focused on geomorphology attributes only. Motivated by this fact, the objective of this study is to develop a conceptual design for a Stream Island Index (SII) as a template for physical habitat complexity assessment in stream restoration projects. Specific purposes included: (a) to examine stream island conceptual models; (b) to develop obvious and comprehensive explanations of stream island development by considering attributes from the geomorphology, hydraulics, and ecology.

Material and methods

Stream islands versus stream bars

It is important to understand how stream islands and stream bars are different. Natural streams constantly exhibit distinctive behavior and patterning in their properties from a geomorphic standpoint. Studying the stream features is also always dependent on the river morphology and time. Over time, bed topography is influenced by both local and systematic variations in sediment supply and the stream power so that it always changes. These changes affect the diversity and complexity of stream features including stream bars and stream islands. A stream bar is defined, following the American Society of Civil Engineers (ASCE) Task Force (1966), as a bedform with a length of the same order of magnitude as the channel width and height comparable to the depth of the generating flow (Rice et al., 2009). As a result, it may be stated that bars are sediment storage regions within streams as well as energy dissipaters that aid in stream configuration stabilization. Stream bars are fundamental geomorphic components that should be exposed, solitary, in-channel entities with simple depositional histories regulated by local flow and sediment supply circumstances (Smith, 1974). Stream bars have two key hydraulic phenomena: flow expansion at the bar head generates an upstream diffluence zone and converges downstream at the confluence. Stream bars travel downstream or expand and migrate laterally in steady-state flow, as in meandering streams.

Stream islands differ slightly from stream bars. Although the physical appearance of a stream island is similar to that of a stream bar, there are several aspects of stream islands that stream bars do not have. Stream bars can generate stream islands with some processes over time. The combined processes and requirements of a stream bar to become a stream island can be seen in Figure 1. A simple model of stream bar to island development was proposed to explain the processes and mechanisms involved. Since the stream produces the stream bars, and the stream bars develop the stream islands, there are two major phases. During the first phase, the stream frequently runs with transporting sediments and deposits sediment until a limitation height is reached. During phase two, the material that deposited the bar might collect over time, causing the stream bar to become stable, dense, compacted, and variable. We categorized this as the initial stream island development phase. The material sediment can be varied in shape and diameter such as gravel or sand. However, bars should not be thought of as single morphological entities. They often exist as the result of a complex erosional and depositional chronology linked to the nature of the flood series following stream bar initiation.

The conceptual framework for stream island development

The majority of studies have documented the formation of stream islands in relation to their specific study site; for example, Gurnell et al. (2001) investigated the influence of riparian vegetation, sediment type, and hydrologic regime on island formation in the Fiume Tagliamento in Italy. They created a conceptual model for island formation in the research area and discovered that islands arise by channel avulsion or vegetation on exposed gravel bars. Popov (1962) defined the types of island modifications that he noticed in the River Ob in Russia. Meanwhile, Osterkamp (1998) examined all of the processes that might be linked with islands in more detail. He proposed categorizing islands into at least eight groups depending on their development process, as in the preceding explanations. Cooperman and Brewer (2005) predicted that fluvial dynamics influence the maturation of stream islands and that patterns of vegetation distribution would correlate to patterns of island growth (Figure 2). In general, stream island formation processes consist of 9 categories: avulsion, gradual erosion, lateral shifts, bar/riffle stabilization, structural features, flood deposits, lee deposits, mass movement, and reservoir installation.

The conceptual framework for stream island development was designed for specific purposes such as stream health and stream restoration. The ecological variables in vegetation development

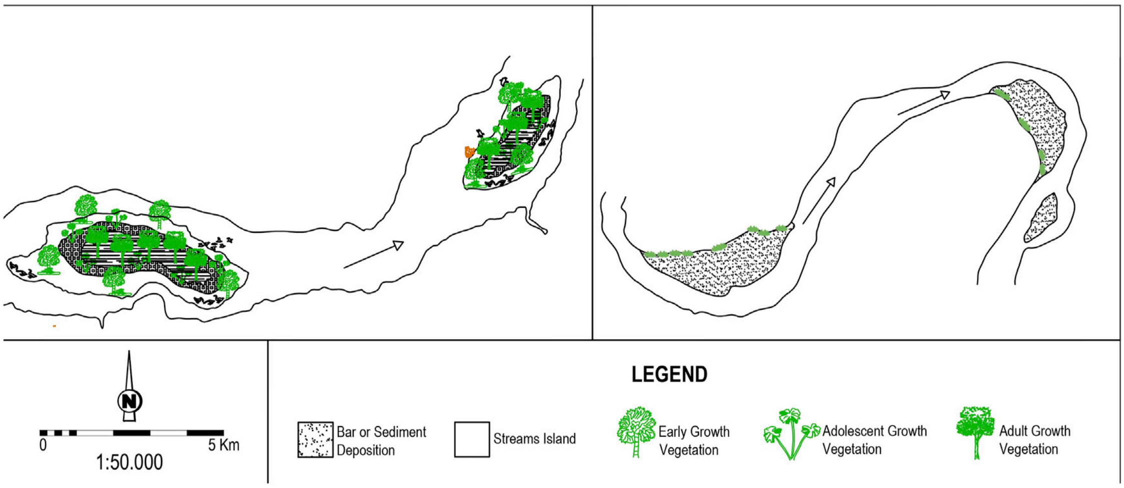

FIGURE 1
A typical schematic design of stream islands versus stream bars.

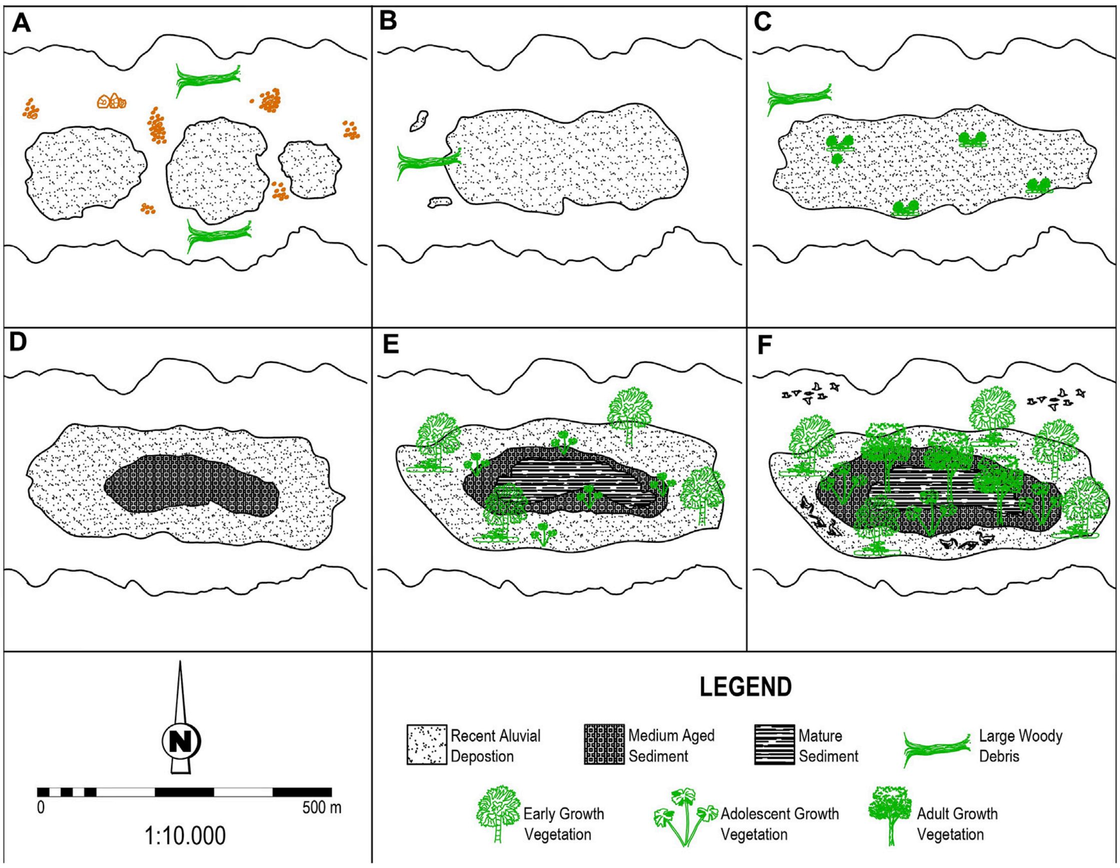

FIGURE 2
The step-by-step process of concept design of stream island development (**(A)** Initial formation of bars; **(B)** Accumulated bar with woody debris; **(C)** Bar with early vegetation growth; **(D)** Sediment deposition stabilized; **(E)** Initial stream island; **(F)** Established stream island).

and microinvertebrate indicators should be counted in stream island development. The degree of vegetation development on stream islands is likely to be related to the amount of time the surface has been exposed above the seasonal low-water level, the position of the water table, the physical character of sediments and their stability, and the types of vegetation available for

TABLE 1 Stream island habitats.

Habitat type	Definition
Island Head	The starting point of an island within a stream. Typically, the surface material is rough, such as gravel and pebbles. Typically, this phenomenon is caused by erosion caused by high speed, although it can result in deposition due to a reverse current
Island Tail	The terminal point of an island located along the course of a river. The uppermost layer of the ground is composed of small-sized rocks and pebbles. Typically, the flow velocity or current is slower at the downstream side of a stream island compared to its upstream side
Island Edge	Any length of island edge that does not occur at the head or tail of an island but on a side of the island that is parallel to the flow and subject to steady and consistent flow forces. There is a wide variety of velocities and substrate kinds in between
Inner Island	The central area of the island that has permanent vegetation, the highest elevation, and is usually dry
Transitional Area	Area between the inner and outside island
Outside Island	A zone bordered by moving water. This location has sparse vegetation growth. The bank slope is usually rather level, with embedded sand and/or pebbles as the substrate

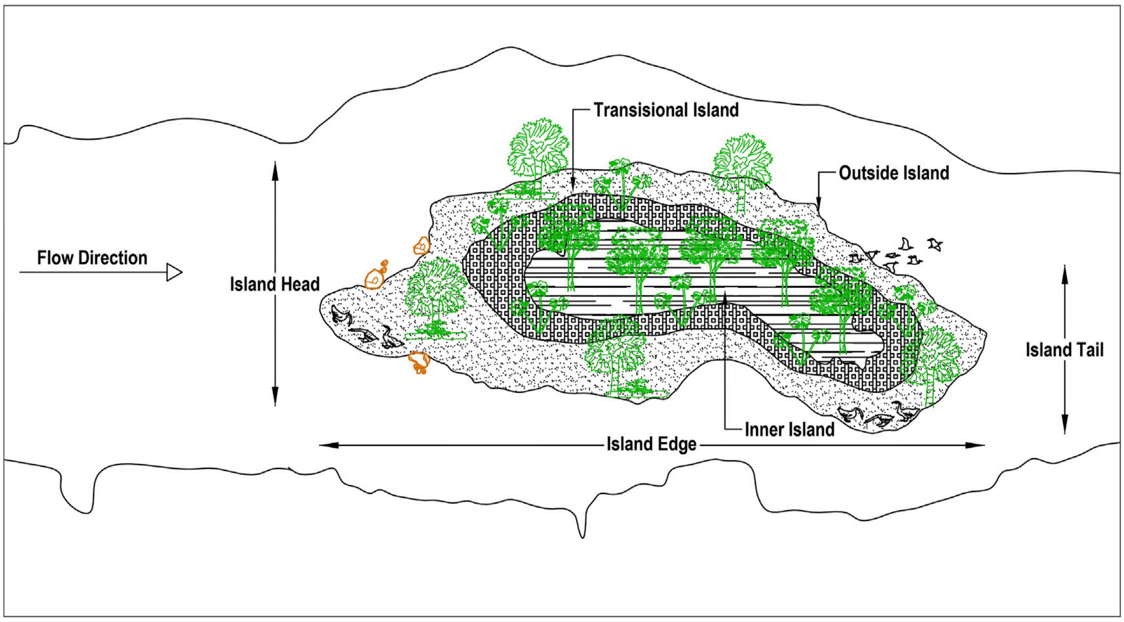

FIGURE 3
A typical design of habitat island types.

colonization. Depending on these factors, newly formed stream islands are progressively vegetated as they accrete vertically and laterally and it thus becomes difficult to define where an initial stream island becomes a complex stream island. There are multiple stream island habitat types based on a literature review (Table 1; Figure 3).

Results and discussion

This study proposes a conceptual framework for developing a stream island evaluation index for sustainable stream restoration projects. It seems essential that a serious attempt be made to design a system that can identify the overall stream island condition. Once a generalized stream island system is set up as a controlling framework, supplementary indexes for specific purposes and locations can be added.

A proposed methodology for a stream island index (SII)

This study provides a comprehensive methodological process for developing a conceptual framework of the Stream Island Index (SII) (Figure 4; Table 2). The purpose should be defined first. In constructing a conceptual framework, this study emphasizes the ecological aspect in addition to the hydraulics and geomorphology attributes. In the framework of a design and method study, it appears necessary to create and validate an index for measuring the parameters involved. A considerable effort was made to develop an index system capable of measuring the overall status of stream islands. In order to develop an index, first it is important to identify the concept or variable to measure and then the selected variables should be included in the developing index. Then, assign scores to each variable. The scores should be based on the relative importance

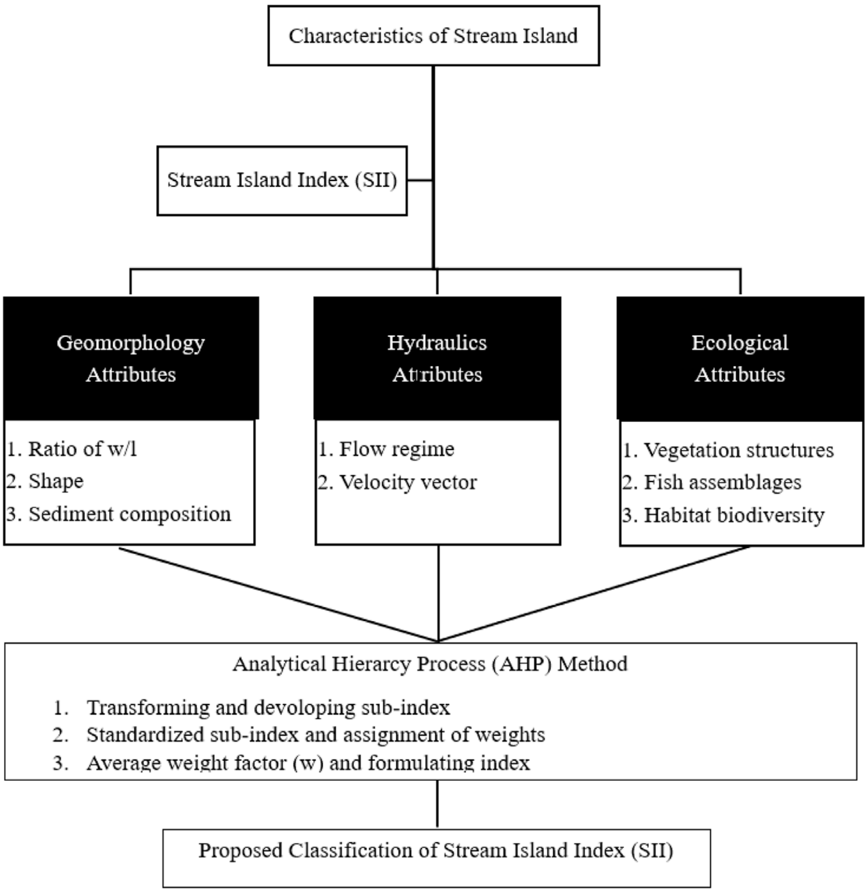

FIGURE 4
A conceptual framework of the Stream Island Index (SII).

TABLE 2 Methods for developing SII.

No.	Stages	Spatial data analysis	Interviews with experts	Field survey measurements
1	Screening and selecting attributes	●	●	●
2	Transforming and developing sub-indices	●		●
3	Assignment of weights	●	●	
4	Formulating an index	●		

of each variable to the concept or variable. This means the level or weight of importance is defined. The next step is to combine the scores of the individual variables to create the index. Detailed steps to create an index can be seen in Table 2. According to a previous study (Chavez and Alipaz, 2006), one common approach is to take the average of the scores of the individual variables. Therefore, in this offered analysis, an index formed by attributes meeting the above criteria could be universally applied, which would significantly increase their usefulness in establishing the development of the SII in a matrix scheme. Numerically, the SII can therefore be represented as:

$$SII = \sum_{i=1}^{n} w_i C_i \quad (1)$$

Where w_i is the average weight factor for the i^{th} parameter, and C_i is the standardized sub-index for the i^{th} parameter. Each quality value is then multiplied by an average weight factor, to take into account the relative contribution of each variable to the overall index.

This study also used the Analytical Hierarchy Process (AHP) method to process the development of the SII. In the early 1970s, Thomas L. Saaty invented a structured mathematics and psychology strategy for organizing and analyzing complex decisions by entailing and decomposing a complex decision into a set of criteria and subcriteria. This method allows the decision-maker to use a pairwise comparison matrix to analyze the relative value of each criterion and subcriterion. In the process of AHP, it is also necessary to have the weighted importance of each criterion and subcriterion, as well as

TABLE 3 Ratio scale used with 2, 4, 6, and 8 as the mid-values.

Ratio scale	Comparison between two factors
1	Equally important
3	Moderately important
5	Strongly important
7	Very strongly important
9	Extremely important

the overall ranking of the alternatives, in order to analyze and calculate it.

In the context of applying the AHP to the development of the SII, there are several stages for developing the SII (Table 2). First, spatial data should be generated by spatial analysis that reveal the geometric or geographic properties. Spatial data could use a computational model such as a Geographic Information System (GIS)-based model. This study proposes the rapid advancement of ArcGIS combined with Google-Earth software in spatial analyses of environmental stream island and habitat data triggered the need for change in methods of field survey measurements. Next, interviews with experts would be conducted in order to proceed with the AHP method. Expert judgments have often been used to acquire criteria weights when there is a lack of the required data (Reza et al., 2013) and software such as Expert Choice 11.0 is used to analyze multi-criterion decision-making problems based on the AHP approach. The experts thus evaluate the various criteria and alternatives using a numerical scale, as shown in Table 3. Overall, AHP is considered a robust decision-making tool in order to develop the SII. One restriction is that AHP is sensitive to the decision-maker's pairwise comparisons.

Concerning field survey measurements especially in fish assemblages indicators, sampling fish by using an electrofishing device is the appropriate method. This method identifies specific fish habitat use in streams. Moreover, the snorkeling method also can be used in clear stream conditions with some constraints such as the observer's ability to identify species and is characterized by spatial and temporal heterogeneity across various scales.

The understanding of SII in stream restoration projects

Civil engineers, environmental engineers, stream ecologists, aquatic biologists, and other stakeholders all embark on stream restoration projects from a disciplinary perspective. However, the lack of integration among these various practitioners has resulted in limited project success in many cases. Stream islands in restoration projects have an important role since ecological failures have often occurred from engineering designs that ignore their existence. Therefore, to avoid such effects, it is necessary to ensure that the geomorphology, hydraulics, and ecological attributes of stream islands are mutually considered within the stream restoration design process. The proposed design framework for stream restoration projects, as conceptualized by naturalization, applies fluvial geomorphology, hydraulic engineering, and stream ecology to provide a more robust design approach to design in human-dominated stream management, and has a greater potential of success in achieving ecosystem stability. Integration of three attributes requires a three-dimensional view of stream island morphology and hydraulics, along with ecological patterns that express habitat complexity with biological needs. From a new view of stream island habitat and its analysis, ecological criteria will be better integrated into stream restoration projects for application by water resource professionals.

Many previous studies have focused on fluvial systems that maintain stream islands by addressing the need to understand aquatic ecology ecosystem functioning (e.g., Osterkamp, 1998; Edwards et al., 1999; Gurnell and Petts, 2002; Tockner et al., 2003; Karaus et al., 2005; Francis et al., 2009). Recent research has also highlighted the important role of feedback between organisms and physical processes in determining the spatial structure and dynamics of ecosystems, both terrestrial and aquatic (Francis et al., 2009). One of the results is the aggregating of sediment and hydraulic roughness on the gravel bars, creating the stabilization of the initial stream island. In some cases, the stream island is formed by the gravel bar and the deposition of large woody debris (LWD) above. Usually, organic matter, fine sediments, and creatures (e.g., plant propagules, fish, crustaceans) are caught in and surround deposited large woody debris or vegetation that can support stream island process development (Karaus et al., 2005).

Conclusion

In conclusion, it is important to have a comprehensive methodology as a template for physical habitat complexity assessment in stream restoration projects. This study introduced the Stream Island Index (SII) as a valuable tool for stream restoration practitioners or policymakers by using a single number to measure the quality of stream island habitats. Furthermore, the SII can be used for specific purposes in order to improve the quality and diversity of physical habitats in stream restoration projects. The SII can also be used to monitor and evaluate the stream restoration process in adaptive stream management strategies.

In further studies, some potential variables such as numbers, size, distribution, and location of stream islands and some in-stream features such as riffles, pools, and large woody debris (LWD) could be considered in the SII components in order to assess the physical habitat complexity of stream islands. However, it may be beneficial to develop regional-specific templates within the SII framework. These regional-specific templates would take into account the unique characteristics and dynamics of different geographic regions.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

RT: Conceptualization, Writing–original draft.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The Conceptual Design of Stream Island Index for Physical Habitat Complexity Assessment in Stream Restoration Projects

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Abstract

Most literatures on geomorphology, hydraulics or stream ecology contained no mention or less description about stream island, the process, the development or the ecological advantages provided. Due to a lack of information, research and related data, there were no stream island indexes available for indicating the stream island status. Motivated by the fact, the objective of this study is to develop a conceptual design of Stream Island Index (SII) as a template for physical habitat complexity assessment in stream restoration projects. Specific purposes included: (a) to examine the stream island conceptual models; (b) to develop obvious and comprehensive explanations of the stream island development by considering attributes from the geomorphology, hydraulics and ecological perspective. This study used AHP method as follows screening and selecting attributes, transforming and developing sub-indices, assignment of weights, and

formulating an index. The conclusion is a Stream Island Index (SII) combines the measures of selected physical habitat quality indicators to produce a single dimensionless number, and a novel approach to communicate information on stream island quality status to the public and related policy makers. It seems essential that a serious attempt be developed to design a system that can identify the overall stream island condition. Once a generalized stream island system is set up as a controlling framework, supplementary indexes for specific purposes and location can be added. Therefore, the SII is a promising new tool for stream restoration practitioners, and it has the potential to make a significant contribution to improving the success of stream restoration projects.

Keywords: Index; Habitat Characteristics; Stream Island; Stream Restoration Projects

Introduction

Natural streams are dynamic and physically and biologically very complex (Tockner & Stanford, 2002). The habitat complexity is not only the physical characteristics but also the uses of the streams themselves. Many experts such as river engineers, geomorphologists, civil engineers, and ecologists might well have a similar opinion especially when it is recognized how variable and complex a river with all living beings within can be through time and from reach to reach of the river. Therefore, it is still challenging to discover comprehensive results without considering all the stream variables. Stream island is one of the physical habitat features in streams. In the past, the role of stream islands has been almost totally ignored by civil engineers due to lack of understanding of the geomorphology, hydraulics, and ecological functions of stream island within. In stream restoration projects, the existence of stream island often did not consider as an important variable or major influence in many cases study. Many researchers generally only focused on the permanent islands such as continental fragments, exposed lands in lakes, coral reefs, or barrier islands, few have concept design or further detailed research about the development of stream island in streams. Most literature on geomorphology, hydraulics or stream ecology also contained no mention or less description about stream island in streams, the process, the development, or the further ecological advantages provided. A lot of previous research also only concentrated with the large and braided river such as Tagliamento River, Italy (Gurnell et. al., 2001; Francis et. al, 2009; Comiti et. al., 2011). None or a few research explored about concept design of the island in the stream itself considering the context of the development of physical habitat complexity within.

On the other hand, physical habitat complexity plays an important role in community structure in natural streams along with a variety of geomorphology, hydraulics, and ecological processes (Schluter and Ricklefs, 1993; Rahbek and Graves, 2001). Physical habitat complexity within natural streams should be viewed as planform patterns provide the initial physical habitat template. Heterogeneity and complexity of physical habitat structure were governed by geomorphic, hydraulics, and ecological form and processes associated with a state of dynamic equilibrium. Therefore, it can be expected that changes in geomorphic, hydraulics, and ecological form and processes at the planform scale can be quantified through measurements and assessments. Hence, in the traditional physical habitat complexity assessment in stream restoration projects assessments is often focused geomorphology attributes only. Motivated by the fact, the objective of this study is to develop a conceptual design of Stream Island Index (SII) as a template for physical habitat complexity assessment in stream restoration projects. Specific purposes included: (a) to examine the stream island conceptual models; (b) to develop obvious and comprehensive explanations of the stream island development by considering attributes from the geomorphology, hydraulics and ecological attributes.

Material and methods

Stream islands versus Stream bars

It is important to understand how stream islands and stream bars are different. Natural streams constantly exhibit distinctive behavior and patterning in their properties from a geomorphic standpoint. Studying the stream features also always dependent with the river morphology and time. Over time by time, bed topography is influenced by both local and systematic variation in sediment supply and the stream power so that it always changes. These changes affect the diversity and complexity of stream features including stream bars and stream islands. Stream bar is defined following the American Society of Civil Engineers (ASCE) Task Force (1966) as a bedform with length of the same order of magnitude as the channel width and height comparable to the depth of the generating flow (Rice et. al., 2009). As a result, it may be stated that bars are sediment storage regions within streams as well as energy dissipaters that aid in stream configuration stabilization (Church and Jones, 1982). Stream bars are fundamental geomorphic components that should be exposed, solitary, in-channel entities with simple depositional histories regulated by local flow and sediment supply circumstances (Smith, 1974). Stream bars have two key hydraulic phenomena: flow expansion at the bar head generates an upstream diffluence zone and converges downstream at the confluence. Stream bars travel downstream or expand and migrate laterally in steady-state flow, as in meandering streams.

Stream island differs slightly from stream bar. Although the physical appearance of stream island is similar to that of stream bar, there are several aspects in stream island that the stream bar does not have. Stream bars can generate stream islands with some processes within over time.

Combined process and fulfilled some requirements of the stream bar to become stream island can be seen in Figure 1. A simple model of stream bar to island development was proposed to explain the process and mechanisms involved. Since the stream produces the stream bars, and the stream bars develop the stream islands, there are two major phases. During the first phase, the stream frequently runs with transporting sediments and deposits sediment until a limitation height is reached. During phase two, the material that deposited the bar might collect over time, causing the stream bar to become stable, dense, compacted, and variable. We categorized this phase as an initial stream island development. The material sediment can be varied in shape and diameter such as gravels or sands. However, bars should not be thought of as single morphological entities. They often exist as the result of a complex erosional and depositional chronology linked to the nature of the flood series following stream bar initiation.

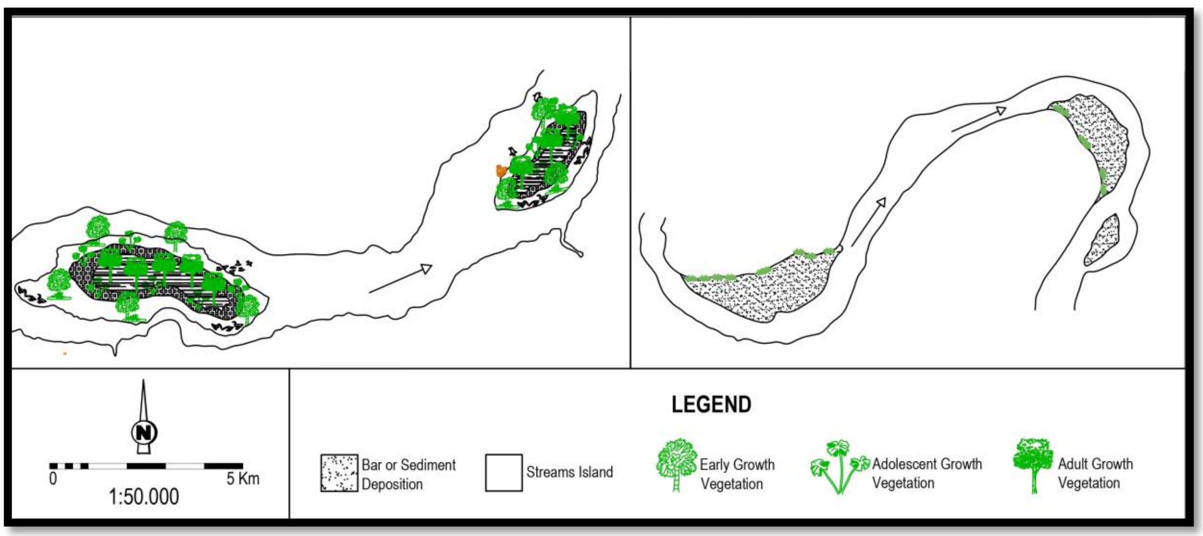

Fig. 1. A schematic typical design of stream islands versus stream bars

The conceptual framework for stream island development

The majority of studies have documented the formation of stream islands in relation to their specific study site; for example, Gurnell et al. (2001) investigated the influence of riparian vegetation, sediment type, and hydrologic regime on island formation in the Fiume Tagliamento, Italy. They created a conceptual model for island formation in the research area and discovered that islands arise by channel avulsion or vegetation on exposed gravel bars. Popov (1962) defined the types of island modifications that he noticed in River Ob, Russia. Meanwhile, Osterkamp (1998) examined all of the processes that might be linked with islands in more detail. He proposed categorizing islands into at least eight groups depending on their development process, as in the preceding explanations. Cooperman and Brewer (2005) predicted that fluvial dynamics influence the maturation of stream islands, and that patterns of vegetation distribution would correlate to patterns of island growth (Figure 2). In general, stream island formation processes consisted of 9 categories: avulsion, gradual erosion, lateral shifts, bar/riffle stabilization, structural features, flood deposits, lee deposits, mass movement and reservoir installation.

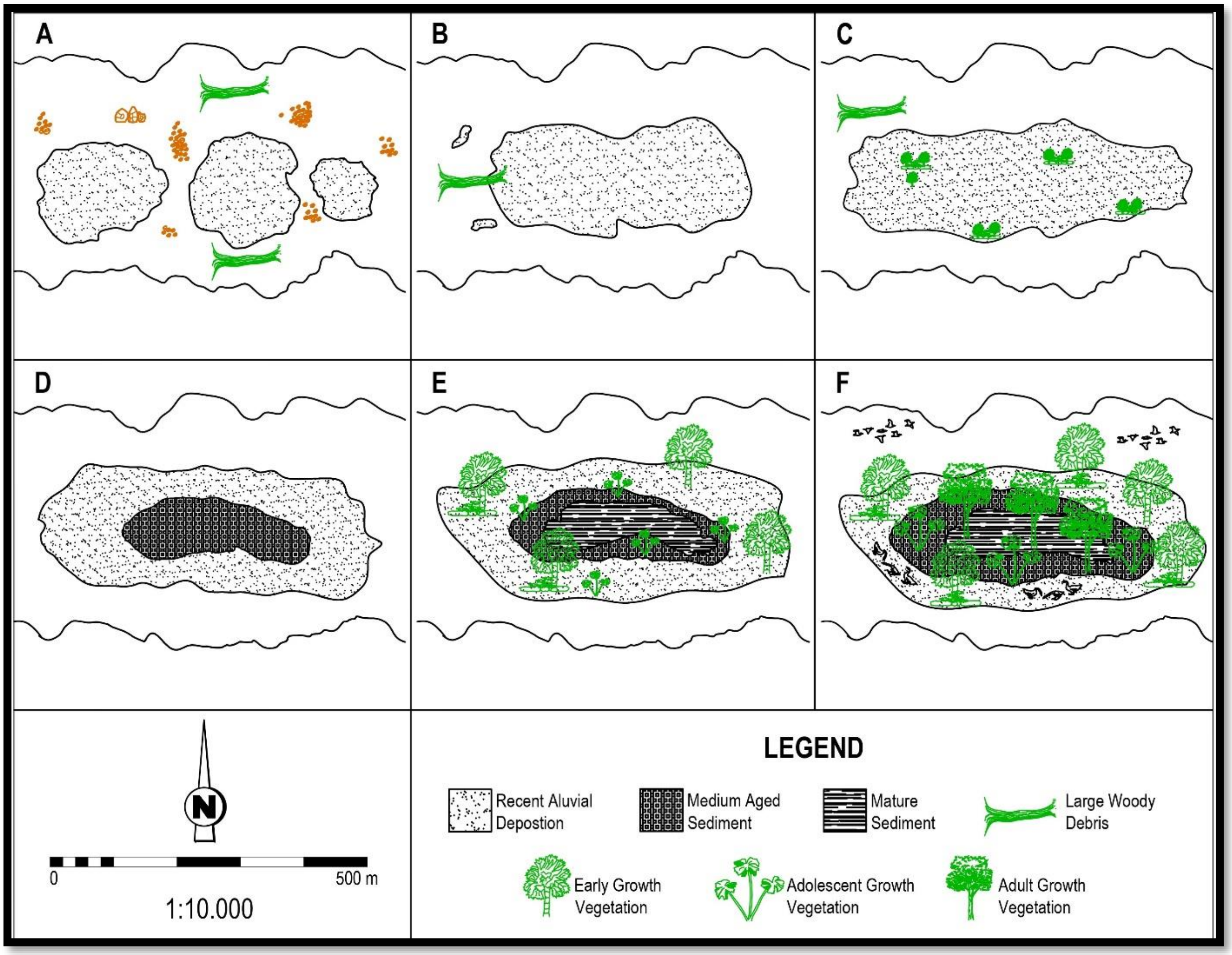

Fig. 2. The step-by-step process of concept design of stream island development

The conceptual framework for stream island development was designed the standard in order to reach specific purpose such as stream health, stream restoration, etc. The ecological variables in the vegetation development and microinvertebrates indicators should be counted in stream island development. The degree of vegetation development on stream island is likely to be related to the amount of time the surface has been exposed above the seasonal low-water level, the position of water table, the physical character of sediments and their stability and the types of vegetation available for colonization. Depending on these factors, newly formed stream island are progressively vegetated as they accrete vertically and laterally and it thus becomes difficult to define where an initial stream island becomes a complex stream island. There are some terms in habitat types of the stream island introduced based on literature reviews (Table 1 and Figure 3).

Table 1. Habitat of Stream Island

Habitat Types	**Definition**
Island Head	The starting point of an island within a stream. Typically, the surface material is rough, such as gravel and pebbles. Typically, this phenomenon is caused by erosion caused by high speed, although it can result in deposition due to a reverse current.
Island Tail	The terminal point of an island located along the course of a river. The uppermost layer of the ground is composed of small-sized rocks and pebbles. Typically, the flow velocity or current is slower at the downstream side of a stream island compared to its upstream side.
Island Edge	Any length of island edge that does not occur at the head or tail of an island but on a side of the island that is parallel to the flow and subject to steady and consistent flow forces. There is a wide variety of velocities and substrate kinds in between.
Inner Island	The central area of island that has permanent vegetation, the highest elevation, and is usually dry.
Transitional Area	Area between inner and outside island.
Outside Island	A zone bordered by moving water. This location has sparse vegetation growth. The bank slope is usually rather level, with embedded sand and/or pebbles as the substrate.

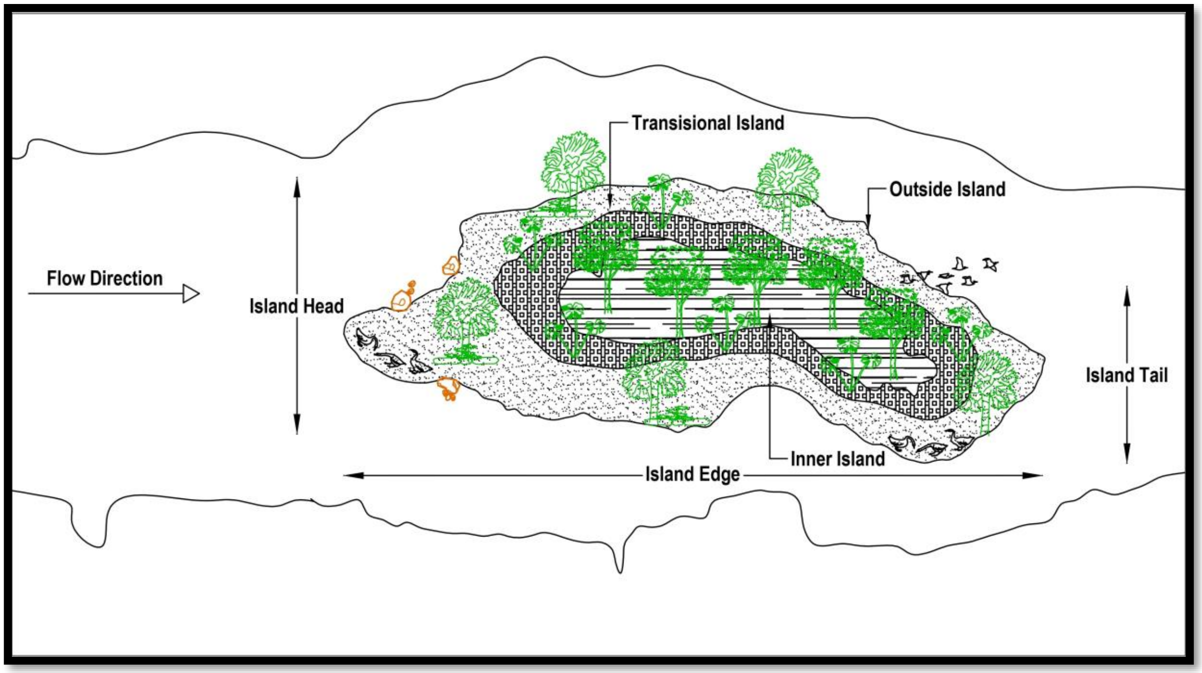

Fig. 3. A typical design of habitat island types

Results and Discussion

This study proposes a conceptual framework for developing stream island evaluation index towards sustainable stream restoration project. It seems essential that a serious attempt be developed to design a system that can identify the overall stream island condition. Once a generalized stream island system is set up as a controlling framework, supplementary indexes for specific purposes and location can be added.

A Proposed Methodology for Stream Island Index (SII)

This study provided a comprehensive methodological process for developing a conceptual framework of the Stream Island Index (SII) (Figure 4 and Table 2). The purpose should be defined first. In constructing a conceptual framework, this study emphasized the ecological aspect in addition to the hydraulics and geomorphology attributes. In the framework of a design and method study, it appears necessary to create and validate an index for measuring the parameters involved. A considerable effort was made to develop an index system capable of measuring the overall status of stream island. In order to develop an index, first it is important to identify the concept or variable to measure and then the selected variables should be included in the developing index. Then, assign scores to each variables. The scores should be based on the relative importance of each variables to the concept or variable. It means the level or weight of importance should be defined. Next step is combine the scores of the individual variables to create the index. Detail steps to create an index can be seen on Table 2. According to previous study (Chavez and Alipaz, 2006), one common approach is to take the average of the scores of the individual variables. Therefore, in this offered analysis, an index formed by attributes meeting the above criteria could be universally applied, which would significantly increase their usefulness in establishing the development of Stream Islands Index (SII) in a matrix scheme. Numericaly, the SII can therefore be represented as:

$$\mathrm{SII} = \sum_{i=1}^{n} w_i C_i \quad (1)$$

Where w_i was the average weight factor for the i^{th} parameter, and C_i was the standardized sub-index for the i^{th} parameter. Each quality value was then multiplied by an average weight factor, to take into account the relative contribution of each variable to the overall index.

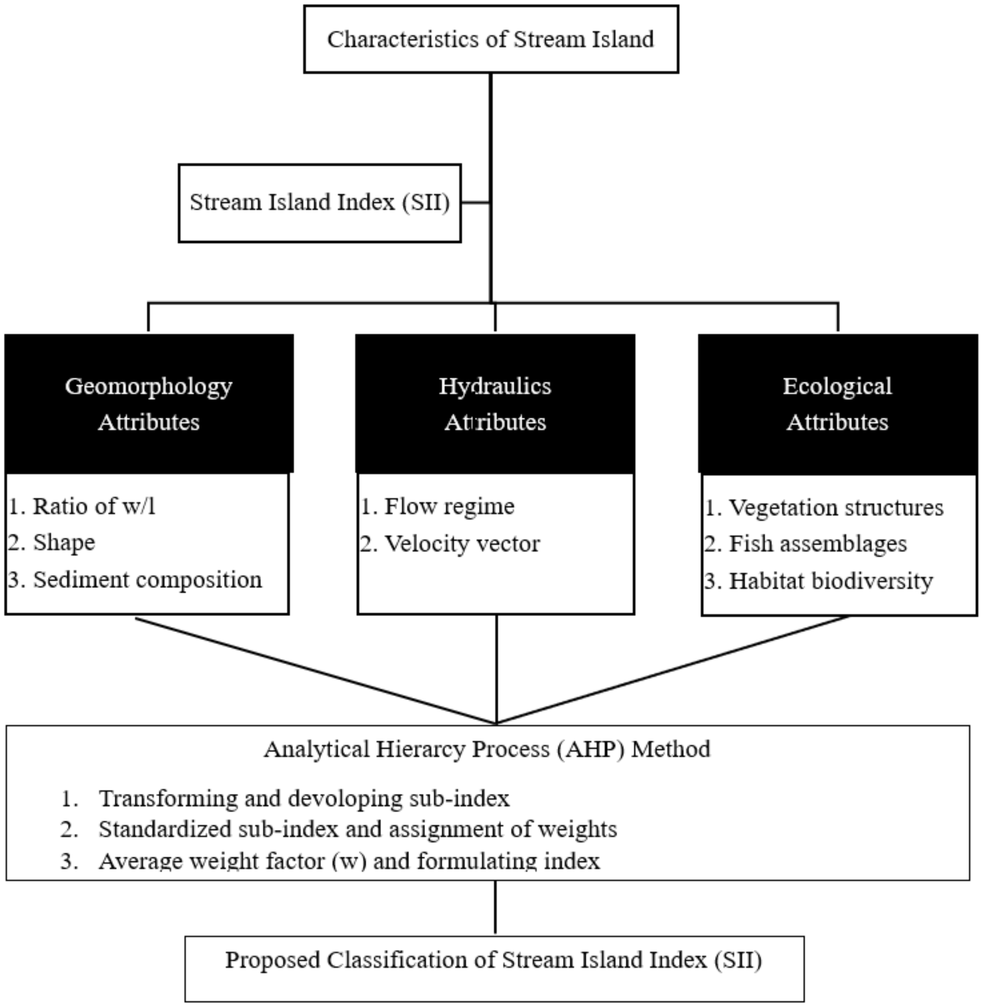

Fig. 4. A conceptual framework of the Stream Island Index (SII)

Table 2. Methods for developing SII

No.	Stages	Spatial data analysis	Interviews with experts	Field survey measurements
1	Screening and selecting attributes	●	●	●
2	Transforming and developing sub-indices	●		●
3	Assignment of weights	●	●	
4	Formulating an index	●		

This study also used the Analytical Hierarchy Process (AHP) method. This method is a structured mathematics and psychology technique for organizing and analyzing complex decisions that was developed by Thomas L. Saaty in the 1970s and has been refined since then. AHP involves breaking down a complex decision into a hierarchy of criteria and subcriteria. The decision-maker then compares the relative importance of each criterion and subcriterion using a pairwise comparison matrix. The AHP software then calculates the weighted importance of each criterion and subcriterion, as well as the overall ranking of the alternatives. AHP is a powerful tool for decision-making, but it is important to use it carefully and to be aware of its limitations. One limitation is that AHP is sensitive to the pairwise comparisons made by the decision-maker. If the decision-maker is biased or does not have a good understanding of the problem, the results of the AHP analysis may be inaccurate.

In context of Analytical Hierarchy Process (AHP) process, there are several stages for developing SII (Table 2). First, spatial data should be performed by spatial analysis that reveal the geometric or geographic properties of data. Spatial data could use a computational model such as Geographic Information System (GIS)-based model. This study proposed the rapid advancement of ArcGIS combined with Google-Earth software in spatial analyses of environmental stream island and habitat data triggered the need for change in methods of field survey measurements. Next method is interviews with experts in order to process the Analytical Hierarchy Process (AHP) method. Expert judgments have often been used to acquire criteria weights when there was a lack of the required data (Reza et al., 2013) and used the various softwares such as Expert Choice 11.0 to analyze multi-criterion decision-making problems based on the AHP approach. The experts thus evaluated the various criteria and alternatives using a numerical scale, as shown in Table 3.

Table 3. Ratio scale used with note 2, 4, 6, and 8 are the mid-values between two adjoining ones

Ratio Scale	Comparison between two factors
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The understandings of SII in stream restoration projects

Civil engineers, environmental engineers, stream ecologists, aquatic biologists and other stakeholders all embark on stream restoration projects from a disiplinary perspective. However, lack of integration among these various practitioners has resulted in limited project success in many cases. Stream island in restoration projects has important role since ecological failures has often occured from engineering designs that ignoring the existance of it. Therefore, to avoid such effects, it is necessary to ensure that geomorphology, hydraulics and ecological attributes from stream island are mutually considered within the stream restoration design process. The proposed design framework to stream restoration projects, as conceptualized by naturalization, applies fluvial geomorphology, hydraulic engineering, and stream ecology to provide a more robust design approach to design in human-dominated stream management, and has greater potential of success to achieve ecosystem stability. Integration of three attributes requires a three-dimentional view of stream island morphology and hydraulics, along with ecological patterns that express habitat complexity with biological needs. From a new view of stream island habitat and its analysis, ecological criteria will be better integrated into stream restoration projects for application by water resource proffesionals.

Many previous studies has focused on fluvial systems that maintain stream islands with addressing the needs of understanding in aquatic ecology ecosystem functioning (e.g. Osterkamp, 1998; Edwards et al., 1999; Gurnell and Petts, 2002; Tockner et. al., 2003; Karaus et al., 2005; Francis et. al., 2008). Recent research has also highlighted the important role of feedbacks between organisms and physical processes in determining the spatial structure and dynamics of ecosystems, both terrestrial and aquatic (Francis et. al., 2008). One of the results is the aggregating of sediment and hydraulic roughness on the gravel bars, created the stabilization of the initial stream island. For some cases, the stream island formed by the gravel bar and the deposition of large woody debris (LWD) above. Organic detritus, fine sediments and organisms (e.g. plant propagules, fish, invertebrates) mostly are trapped in and around the deposited LWD or vegetation (e.g. Karaus et al., 2005).

Conclusion

In conclusion, the conceptual design of the Stream Island Index (SII) is comprehensive methodology development as a template for physical habitat complexity assessment in stream restoration projects. The SII combines the measures of selected physical habitat quality parameters to produce a single dimensionless number, and a novel approach to communicate information on stream island quality status to the public and related policy makers. It also has the potential to be a valuable tool for stream restoration practitioners. The SII can be used to set specific goals for restoration projects, such as increasing the number of islands in a stream or improving the physical habitat diversity. The SII can be used to track progress over time to see how well restoration projects are meeting their goals. Moreover, it also can be used to compare the success of different restoration approaches, such as using different types of in-stream structures or different planting strategies. Finally, the SII also can be used to communicate the value of stream restoration to the public by explaining how the index works and how it can be used to assess the quality of stream habitat. Therefore, the SII is a promising new tool for stream restoration practitioners, and it has the potential to make a significant contribution to improving the success of stream restoration projects.

For future works, there are several potential considerations for the development of the Stream Island Index in habitat assessment such as the expansion of spatial coverage of Stream Island Index by recommendations from stakeholders of land management (federal agencies, state, tribal, and private lands). It also will provide a more comprehensive assessment of physical habitat complexity in stream restoration projects. However, it may be beneficial to develop regional-specific templates within the Stream Island Index framework. These regional-specific templates would take into account the unique characteristics and dynamics of different geographic regions.

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The conceptual design of a stream island index for physical habitat complexity assessment in stream restoration projects

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Most literature on geomorphology, hydraulics, or stream ecology contained either no mention or a brief description of stream islands, the process, the development, or the ecological advantages provided. Due to a lack of information, research, and related data, there were no stream island indexes available to indicate the stream island status. Motivated by this fact, the objective of this study is to develop a conceptual design for a Stream Island Index (SII) as a template for physical habitat complexity assessment in stream restoration projects. Specific purposes included: 1) to examine stream island conceptual models; 2) to develop obvious and comprehensive explanations for stream island development by considering attributes from the geomorphic, hydraulic, and ecological perspectives. This study used the AHP method for screening and selecting attributes, transforming and developing sub-indices, assigning weights, and formulating an index. The conclusion is an SII that combines the measures of selected physical habitat quality indicators to produce a single dimensionless number, and a novel approach to communicate information on stream island quality status to the public and related policymakers. It seems essential that a serious attempt be developed to design a system that can identify the overall stream island condition. Once a generalized stream island system is set up as a controlling framework, supplementary indexes for specific purposes and locations can be added. Therefore, the SII is a promising new tool for stream restoration practitioners, and it has the potential to make a significant contribution to improving the success of stream restoration projects.

KEYWORDS

index, habitat characteristics, stream island, stream restoration projects, AHP

Introduction

Natural streams are dynamic and physically and biologically very complex (Tockner and Stanford, 2002). The habitat complexity is not only the physical characteristics but also the uses of the streams themselves. Many experts such as river engineers, geomorphologists, civil engineers, and ecologists might well have a similar opinion especially when it is recognized how variable and complex a river with all living beings within can be through time and from reach to reach of the river. Therefore, it is still challenging to discover comprehensive results without considering all the stream variables. Stream islands are one of the physical habitat features in streams. In the past, the role of stream islands has been almost totally ignored by civil engineers due to a lack of understanding of the geomorphology, hydraulics, and

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ecological functions of stream islands. In stream restoration projects, the existence of stream islands often was not considered as an important variable or major influence in many case studies. Many researchers generally only focused on permanent islands such as continental fragments, exposed lands in lakes, coral reefs, or barrier islands, and few have concept designs or further detailed research about the development of stream islands in streams. Most literature on geomorphology, hydraulics, or stream ecology also contained either no mention or a brief description of stream islands in streams, the process, the development, or the further ecological advantages provided. A lot of previous research also only concentrated on large and braided rivers such as the Tagliamento River in Italy (Gurnell et al., 2001; Francis et al., 2009; Comiti and Da Canal, 2011). Few research studies have explored a concept design of the island in the stream itself considering the context of the development of physical habitat complexity within.

Physical habitat complexity plays an important role in community structure in natural streams along with a variety of geomorphology, hydraulics, and ecological processes (Schluter and Ricklefs, 1993; Rahbek and Graves, 2001). Physical habitat complexity within natural streams should be viewed as planform patterns that provide the initial physical habitat template. The heterogeneity and complexity of physical habitat structures are governed by geomorphic, hydraulic, and ecological forms and processes associated with a state of dynamic equilibrium. Therefore, it can be expected that changes in geomorphic, hydraulic, and ecological forms and processes at the planform scale can be quantified through measurements and assessments. Hence, the traditional physical habitat complexity assessment in stream restoration project assessments is often focused on geomorphology attributes only. Motivated by this fact, the objective of this study is to develop a conceptual design for a Stream Island Index (SII) as a template for physical habitat complexity assessment in stream restoration projects. Specific purposes included: (a) to examine stream island conceptual models; (b) to develop obvious and comprehensive explanations of stream island development by considering attributes from the geomorphology, hydraulics, and ecology.

Material and methods

Stream islands versus stream bars

It is important to understand how stream islands and stream bars are different. Natural streams constantly exhibit distinctive behavior and patterning in their properties from a geomorphic standpoint. Studying the stream features is also always dependent on the river morphology and time. Over time, bed topography is influenced by both local and systematic variations in sediment supply and the stream power so that it always changes. These changes affect the diversity and complexity of stream features including stream bars and stream islands. A stream bar is defined, following the American Society of Civil Engineers (ASCE) Task Force (1966), as a bedform with a length of the same order of magnitude as the channel width and height comparable to the depth of the generating flow (Rice et al., 2009). As a result, it may be stated that bars are sediment storage regions within streams as well as energy dissipaters that aid in stream configuration stabilization (Church and Jones, 1982). Stream bars are fundamental geomorphic components that should be exposed, solitary, in-channel entities with simple depositional histories regulated by local flow and sediment supply circumstances (Smith, 1974). Stream bars have two key hydraulic phenomena: flow expansion at the bar head generates an upstream diffluence zone and converges downstream at the confluence. Stream bars travel downstream or expand and migrate laterally in steady-state flow, as in meandering streams.

Stream islands differ slightly from stream bars. Although the physical appearance of a stream island is similar to that of a stream bar, there are several aspects of stream islands that stream bars do not have. Stream bars can generate stream islands with some processes over time. The combined processes and requirements of a stream bar to become a stream island can be seen in Figure 1. A simple model of stream bar to island development was proposed to explain the processes and mechanisms involved. Since the stream produces the stream bars, and the stream bars develop the stream islands, there are two major phases. During the first phase, the stream frequently runs with transporting sediments and deposits sediment until a limitation height is reached. During phase two, the material that deposited the bar might collect over time, causing the stream bar to become stable, dense, compacted, and variable. We categorized this as the initial stream island development phase. The material sediment can be varied in shape and diameter such as gravel or sand. However, bars should not be thought of as single morphological entities. They often exist as the result of a complex erosional and depositional chronology linked to the nature of the flood series following stream bar initiation.

The conceptual framework for stream island development

The majority of studies have documented the formation of stream islands in relation to their specific study site; for example, Gurnell et al. (2001) investigated the influence of riparian vegetation, sediment type, and hydrologic regime on island formation in the Fiume Tagliamento in Italy. They created a conceptual model for island formation in the research area and discovered that islands arise by channel avulsion or vegetation on exposed gravel bars. Popov (1962) defined the types of island modifications that he noticed in the River Ob in Russia. Meanwhile, Osterkamp (1998) examined all of the processes that might be linked with islands in more detail. He proposed categorizing islands into at least eight groups depending on their development process, as in the preceding explanations. Cooperman and Brewer (2005) predicted that fluvial dynamics influence the maturation of stream islands and that patterns of vegetation distribution would correlate to patterns of island growth (Figure 2). In general, stream island formation processes consist of 9 categories: avulsion, gradual erosion, lateral shifts, bar/riffle stabilization, structural features, flood deposits, lee deposits, mass movement, and reservoir installation.

The conceptual framework for stream island development was designed for specific purposes such as stream health and stream restoration. The ecological variables in vegetation development and microinvertebrate indicators should be counted in stream

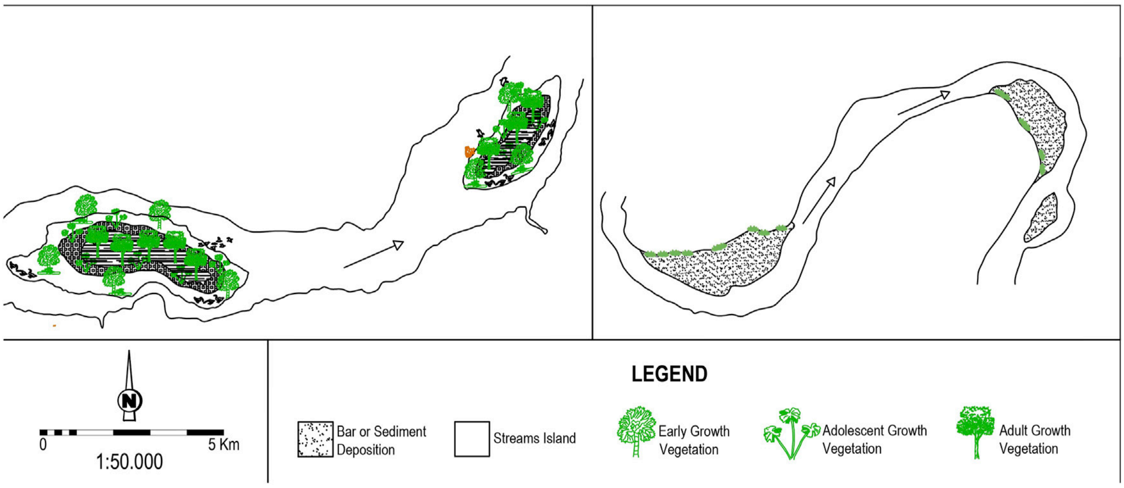

FIGURE 1
A typical schematic design of stream islands versus stream bars.

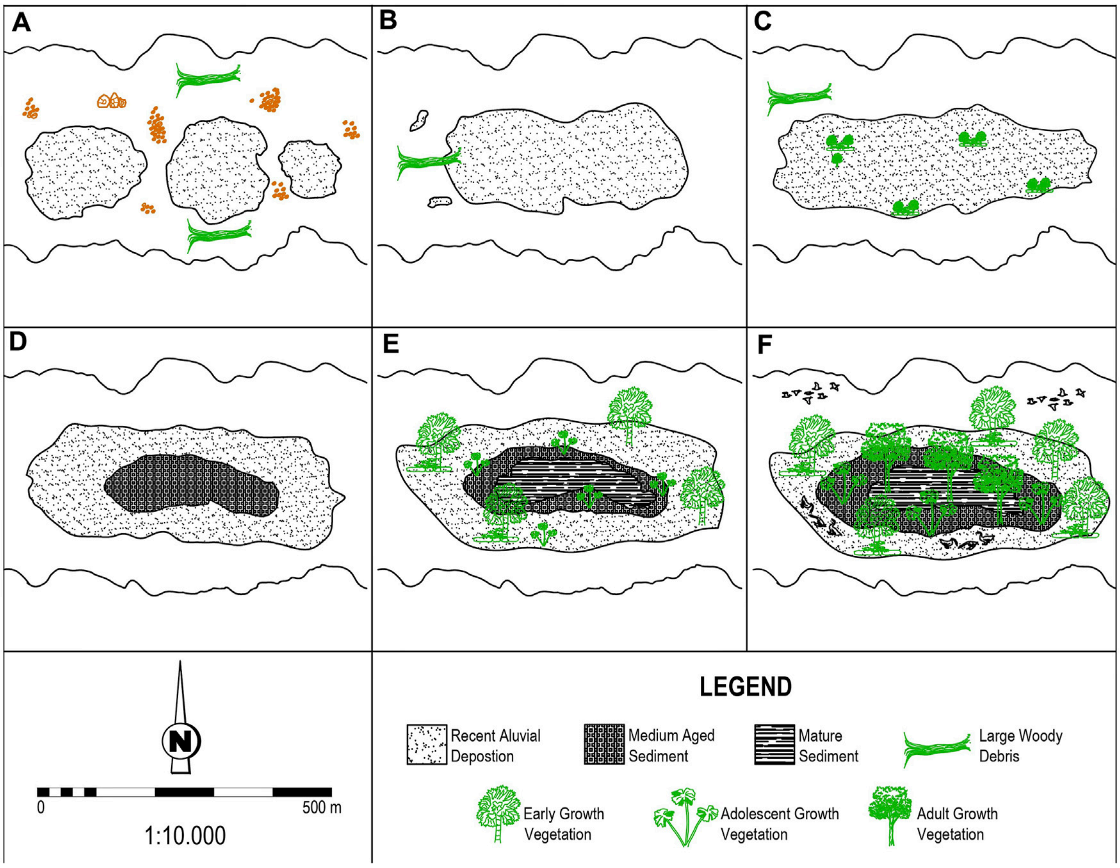

FIGURE 2
The step-by-step process of concept design of stream island development.

island development. The degree of vegetation development on stream islands is likely to be related to the amount of time the surface has been exposed above the seasonal low-water level, the position of the water table, the physical character of sediments and their stability, and the types of vegetation available for colonization. Depending on these factors, newly formed stream

TABLE 1 Stream island habitats.

Habitat type	Definition
Island Head	The starting point of an island within a stream. Typically, the surface material is rough, such as gravel and pebbles. Typically, this phenomenon is caused by erosion caused by high speed, although it can result in deposition due to a reverse current
Island Tail	The terminal point of an island located along the course of a river. The uppermost layer of the ground is composed of small-sized rocks and pebbles. Typically, the flow velocity or current is slower at the downstream side of a stream island compared to its upstream side
Island Edge	Any length of island edge that does not occur at the head or tail of an island but on a side of the island that is parallel to the flow and subject to steady and consistent flow forces. There is a wide variety of velocities and substrate kinds in between
Inner Island	The central area of the island that has permanent vegetation, the highest elevation, and is usually dry
Transitional Area	Area between the inner and outside island
Outside Island	A zone bordered by moving water. This location has sparse vegetation growth. The bank slope is usually rather level, with embedded sand and/or pebbles as the substrate

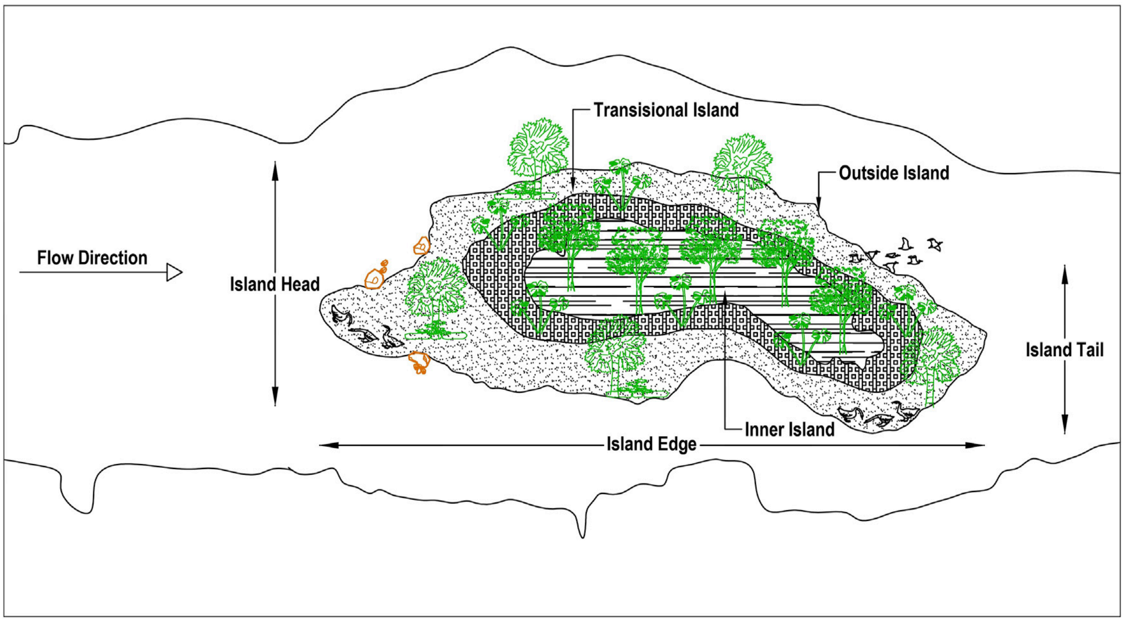

FIGURE 3
A typical design of habitat island types.

islands are progressively vegetated as they accrete vertically and laterally and it thus becomes difficult to define where an initial stream island becomes a complex stream island. There are multiple stream island habitat types based on a literature review (Table 1; Q15 Figure 3).

Results and discussion

This study proposes a conceptual framework for developing a stream island evaluation index for sustainable stream restoration projects. It seems essential that a serious attempt be made to design a system that can identify the overall stream island condition. Once a generalized stream island system is set up as a controlling framework, supplementary indexes for specific purposes and locations can be added.

A proposed methodology for a stream island index (SII) Q16

This study provides a comprehensive methodological process for developing a conceptual framework of the Stream Island Index (SII) (Figure 4; Table 2). The purpose should be defined first. In constructing a conceptual framework, this study emphasizes the ecological aspect in addition to the hydraulics and geomorphology attributes. In the framework of a design and method study, it appears necessary to create and validate an index for measuring the parameters involved. A considerable effort was made to develop an index system capable of measuring the overall status of stream islands. In order to develop an index, first it is important to identify the concept or variable to measure and then the selected variables should be included in the developing index. Then, assign scores to each variable. The scores should be based on the relative importance

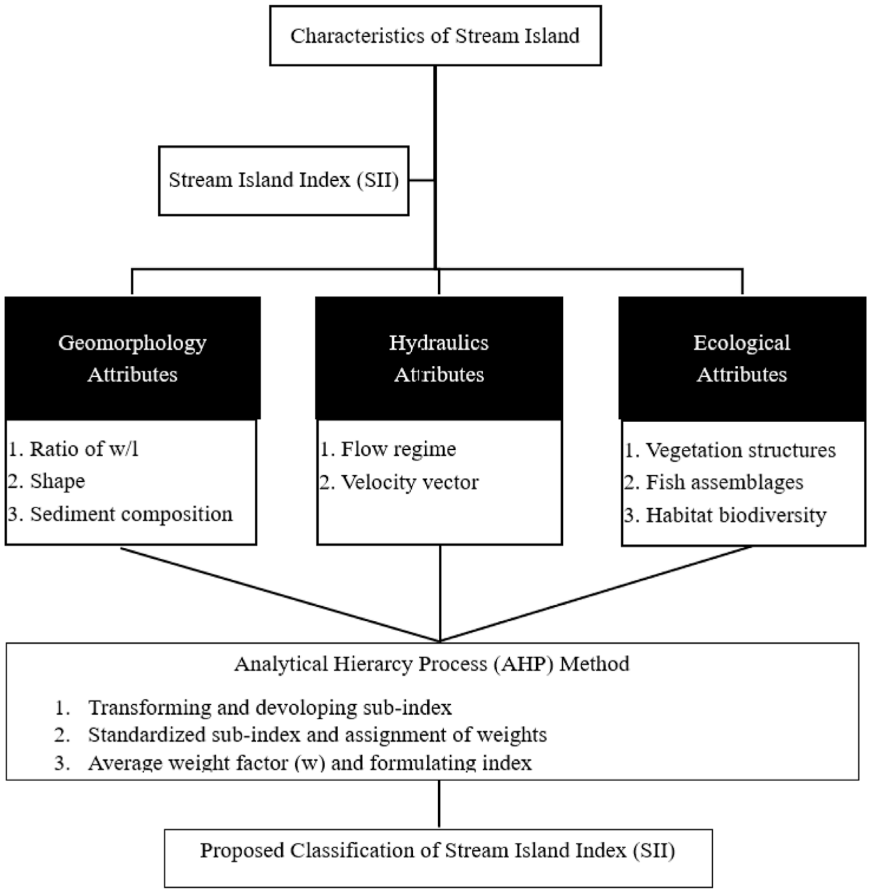

FIGURE 4
A conceptual framework of the Stream Island Index (SII).

TABLE 2 Methods for developing SII.

No.	Stages	Spatial data analysis	Interviews with experts	Field survey measurements
1	Screening and selecting attributes	●	●	●
2	Transforming and developing sub-indices	●		●
3	Assignment of weights	●	●	
4	Formulating an index	●		

of each variable to the concept or variable. This means the level or weight of importance is defined. The next step is to combine the scores of the individual variables to create the index. Detailed steps to create an index can be seen in Table 2. According to a previous study (Chavez and Alipaz, 2006), one common approach is to take the average of the scores of the individual variables. Therefore, in this offered analysis, an index formed by attributes meeting the above criteria could be universally applied, which would significantly increase their usefulness in establishing the development of the SII in a matrix scheme. Numerically, the SII Q17 can therefore be represented as:

$$\mathrm{SII} = \sum_{i=1}^{n} w_i C_i \quad (1)$$

Where w_i is the average weight factor for the ith parameter, and C_i is the standardized sub-index for the ith parameter. Each quality value is then multiplied by an average weight factor, to take into account the relative contribution of each variable to the overall index.

This study also used the Analytical Hierarchy Process (AHP) method to process the development of the SII. In the early 1970s, Thomas L. Saaty invented a structured mathematics and psychology strategy for organizing and analyzing complex decisions by entailing and decomposing a complex decision into a set of criteria and subcriteria. This method allows the decision-maker to use a pairwise comparison matrix to analyze the relative value of each criterion and subcriterion. In the process of AHP, it is also necessary to have the weighted importance of each criterion and subcriterion, as well as

Q19 **TABLE 3 Ratio scale used with 2, 4, 6, and 8 as the mid-values.**

Ratio scale	Comparison between two factors
1	Equally important
3	Moderately important
5	Strongly important
7	Very strongly important
9	Extremely important

the overall ranking of the alternatives, in order to analyze and calculate it.

In the context of applying the AHP to the development of the SII, there are several stages for developing the SII (Table 2). First, spatial data should be generated by spatial analysis that reveal the geometric or geographic properties. Spatial data could use a computational model such as a Geographic Information System (GIS)-based model. This study proposes the rapid advancement of ArcGIS combined with Google-Earth software in spatial analyses of environmental stream island and habitat data triggered the need for change in methods of field survey measurements. Next, interviews with experts would be conducted in order to proceed with the AHP Q18 method. Expert judgments have often been used to acquire criteria weights when there is a lack of the required data (Reza et al., 2013) and software such as Expert Choice 11.0 is used to analyze multi-criterion decision-making problems based on the AHP approach. The experts thus evaluate the various criteria and alternatives using a numerical scale, as shown in Table 3. Overall, AHP is considered a robust decision-making tool in order to develop the SII. One restriction is that AHP is sensitive to the decision-maker's pairwise comparisons.

Concerning field survey measurements especially in fish assemblages indicators, sampling fish by using an electrofishing device is the appropriate method. This method identifies specific fish habitat use in streams. Moreover, the snorkeling method also can be used in clear stream conditions with some constraints such as the observer's ability to identify species and is characterized by spatial Q20 and temporal heterogeneity across various scales.

The understanding of SII in stream restoration projects

Civil engineers, environmental engineers, stream ecologists, aquatic biologists, and other stakeholders all embark on stream restoration projects from a disciplinary perspective. However, the lack of integration among these various practitioners has resulted in limited project success in many cases. Stream islands in restoration projects have an important role since ecological failures have often occurred from engineering designs that ignore their existence. Therefore, to avoid such effects, it is necessary to ensure that the geomorphology, hydraulics, and ecological attributes of stream islands are mutually considered within the stream restoration design process. The proposed design framework for stream restoration projects, as conceptualized by naturalization, applies fluvial geomorphology, hydraulic engineering, and stream ecology to provide a more robust design approach to design in human-dominated stream management, and has a greater potential of success in achieving ecosystem stability. Integration of three attributes requires a three-dimensional view of stream island morphology and hydraulics, along with ecological patterns that express habitat complexity with biological needs. From a new view of stream island habitat and its analysis, ecological criteria will be better integrated into stream restoration projects for application by water resource professionals.

Many previous studies have focused on fluvial systems that maintain stream islands by addressing the need to understand aquatic ecology ecosystem functioning (e.g., Osterkamp, 1998; Edwards et al., 1999; Gurnell and Petts, 2002; Tockner et al., 2003; Karaus et al., 2005; Francis et al., 2009). Recent research has also highlighted the important role of feedback between organisms and physical processes in determining the spatial structure and dynamics of ecosystems, both terrestrial and aquatic (Francis et al., 2009). One of the results is the aggregating of sediment and hydraulic roughness on the gravel bars, creating the stabilization of the initial stream island. In some cases, the stream island is formed by the gravel bar and the deposition of large woody debris (LWD) above. Usually, organic matter, fine sediments, and creatures (e.g., plant propagules, fish, crustaceans) are caught in and surround deposited large woody debris or vegetation that can support stream island process development (Karaus et al., 2005).

Conclusion

In conclusion, it is important to have a comprehensive methodology as a template for physical habitat complexity assessment in stream restoration projects. This study introduced the Stream Island Index (SII) as a valuable tool for stream restoration practitioners or policymakers by using a single number to measure the quality of stream island habitats. Furthermore, the SII can be used for specific purposes in order to improve the quality and diversity of physical habitats in stream restoration projects. The SII Q21 can also be used to monitor and evaluate the stream restoration process in adaptive stream management strategies.

In further studies, some potential variables such as numbers, size, distribution, and location of stream islands and some in-stream features such as riffles, pools, and large woody debris (LWD) could be considered in the SII components in order to assess the physical habitat complexity of stream islands. However, it may be beneficial to develop regional-specific templates within the SII framework. These regional-specific templates would take into account the unique characteristics and dynamics of different geographic regions.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author. Q22

Author contributions

RT: Conceptualization, Writing–original draft. Q23

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Conflict of interest

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The conceptual design of a stream island index for physical habitat complexity assessment in stream restoration projects

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Most literature on geomorphology, hydraulics, or stream ecology contained either no mention or a brief description of stream islands, the process, the development, or the ecological advantages provided. Due to a lack of information, research, and related data, there were no stream island indexes available to indicate the stream island status. Motivated by this fact, the objective of this study is to develop a conceptual design for a Stream Island Index (SII) as a template for physical habitat complexity assessment in stream restoration projects. Specific purposes included: 1) to examine stream island conceptual models; 2) to develop obvious and comprehensive explanations for stream island development by considering attributes from the geomorphic, hydraulic, and ecological perspectives. This study used the AHP method for screening and selecting attributes, transforming and developing sub-indices, assigning weights, and formulating an index. The conclusion is an SII that combines the measures of selected physical habitat quality indicators to produce a single dimensionless number, and a novel approach to communicate information on stream island quality status to the public and related policymakers. It seems essential that a serious attempt be developed to design a system that can identify the overall stream island condition. Once a generalized stream island system is set up as a controlling framework, supplementary indexes for specific purposes and locations can be added. Therefore, the SII is a promising new tool for stream restoration practitioners, and it has the potential to make a significant contribution to improving the success of stream restoration projects.

KEYWORDS

index, habitat characteristics, stream island, stream restoration projects, AHP

Introduction

Natural streams are dynamic and physically and biologically very complex (Tockner and Stanford, 2002). The habitat complexity is not only the physical characteristics but also the uses of the streams themselves. Many experts such as river engineers, geomorphologists, civil engineers, and ecologists might well have a similar opinion especially when it is recognized how variable and complex a river with all living beings within can be through time and from reach to reach of the river. Therefore, it is still challenging to discover comprehensive results without considering all the stream variables. Stream islands are one of the physical habitat features in streams. In the past, the role of stream islands has been almost totally ignored by civil engineers due to a lack of understanding of the geomorphology, hydraulics, and

ecological functions of stream islands. In stream restoration projects, the existence of stream islands often was not considered as an important variable or major influence in many case studies. Many researchers generally only focused on permanent islands such as continental fragments, exposed lands in lakes, coral reefs, or barrier islands, and few have concept designs or further detailed research about the development of stream islands in streams. Most literature on geomorphology, hydraulics, or stream ecology also contained either no mention or a brief description of stream islands in streams, the process, the development, or the further ecological advantages provided. A lot of previous research also only concentrated on large and braided rivers such as the Tagliamento River in Italy (Gurnell et al., 2001; Francis et al., 2009; Comiti and Da Canal, 2011). Few research studies have explored a concept design of the island in the stream itself considering the context of the development of physical habitat complexity within.

Physical habitat complexity plays an important role in community structure in natural streams along with a variety of geomorphology, hydraulics, and ecological processes (Kollmann et al., 1999; Wohl et al., 2005; Rubin et al., 2017; Herrington and Horndeski, 2023; Kaushal et al., 2023; Verdonschot and Verdonschot, 2023). Physical habitat complexity within natural streams should be viewed as planform patterns that provide the initial physical habitat template. The heterogeneity and complexity of physical habitat structures are governed by geomorphic, hydraulic, and ecological forms and processes associated with a state of dynamic equilibrium. Therefore, it can be expected that changes in geomorphic, hydraulic, and ecological forms and processes at the planform scale can be quantified through measurements and assessments. Hence, the traditional physical habitat complexity assessment in stream restoration project assessments is often focused on geomorphology attributes only. Motivated by this fact, the objective of this study is to develop a conceptual design for a Stream Island Index (SII) as a template for physical habitat complexity assessment in stream restoration projects. Specific purposes included: (a) to examine stream island conceptual models; (b) to develop obvious and comprehensive explanations of stream island development by considering attributes from the geomorphology, hydraulics, and ecology.

Material and methods

Stream islands versus stream bars

It is important to understand how stream islands and stream bars are different. Natural streams constantly exhibit distinctive behavior and patterning in their properties from a geomorphic standpoint. Studying the stream features is also always dependent on the river morphology and time. Over time, bed topography is influenced by both local and systematic variations in sediment supply and the stream power so that it always changes. These changes affect the diversity and complexity of stream features including stream bars and stream islands. A stream bar is defined, following the American Society of Civil Engineers (ASCE) Task Force (1966), as a bedform with a length of the same order of magnitude as the channel width and height comparable to the depth of the generating flow (Rice et al., 2009). As a result, it may be stated that bars are sediment storage regions within streams as well as energy dissipaters that aid in stream configuration stabilization. Stream bars are fundamental geomorphic components that should be exposed, solitary, in-channel entities with simple depositional histories regulated by local flow and sediment supply circumstances (Smith, 1974). Stream bars have two key hydraulic phenomena: flow expansion at the bar head generates an upstream diffluence zone and converges downstream at the confluence. Stream bars travel downstream or expand and migrate laterally in steady-state flow, as in meandering streams.

Stream islands differ slightly from stream bars. Although the physical appearance of a stream island is similar to that of a stream bar, there are several aspects of stream islands that stream bars do not have. Stream bars can generate stream islands with some processes over time. The combined processes and requirements of a stream bar to become a stream island can be seen in Figure 1. A simple model of stream bar to island development was proposed to explain the processes and mechanisms involved. Since the stream produces the stream bars, and the stream bars develop the stream islands, there are two major phases. During the first phase, the stream frequently runs with transporting sediments and deposits sediment until a limitation height is reached. During phase two, the material that deposited the bar might collect over time, causing the stream bar to become stable, dense, compacted, and variable. We categorized this as the initial stream island development phase. The material sediment can be varied in shape and diameter such as gravel or sand. However, bars should not be thought of as single morphological entities. They often exist as the result of a complex erosional and depositional chronology linked to the nature of the flood series following stream bar initiation.

The conceptual framework for stream island development

The majority of studies have documented the formation of stream islands in relation to their specific study site; for example, Gurnell et al. (2001) investigated the influence of riparian vegetation, sediment type, and hydrologic regime on island formation in the Fiume Tagliamento in Italy. They created a conceptual model for island formation in the research area and discovered that islands arise by channel avulsion or vegetation on exposed gravel bars. Popov (1962) defined the types of island modifications that he noticed in the River Ob in Russia. Meanwhile, Osterkamp (1998) examined all of the processes that might be linked with islands in more detail. He proposed categorizing islands into at least eight groups depending on their development process, as in the preceding explanations. Cooperman and Brewer (2005) predicted that fluvial dynamics influence the maturation of stream islands and that patterns of vegetation distribution would correlate to patterns of island growth (Figure 2). In general, stream island formation processes consist of 9 categories: avulsion, gradual erosion, lateral shifts, bar/riffle stabilization, structural features, flood deposits, lee deposits, mass movement, and reservoir installation.

The conceptual framework for stream island development was designed for specific purposes such as stream health and stream restoration. The ecological variables in vegetation development

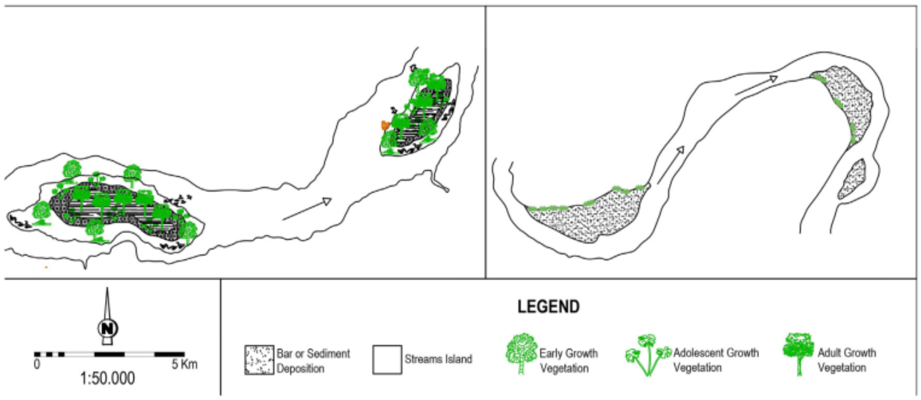

FIGURE 1
A typical schematic design of stream islands versus stream bars.

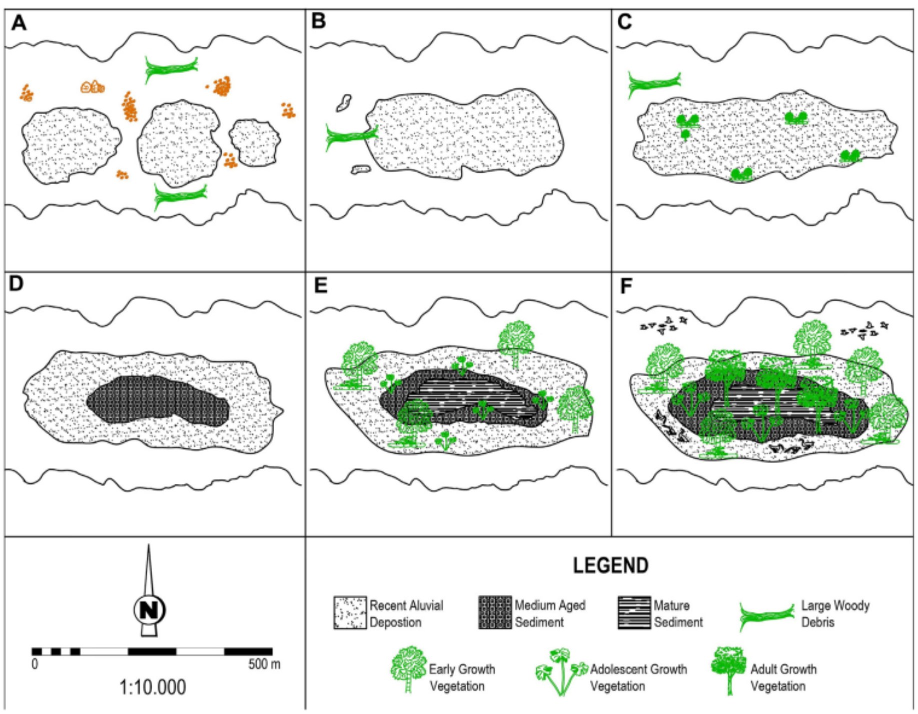

FIGURE 2
The step-by-step process of concept design of stream island development (**(A)** Initial formation of bars; **(B)** Accumulated bar with woody debris; **(C)** Bar with early vegetation growth; **(D)** Sediment deposition stabilized; **(E)** Initial stream island; **(F)** Established stream island).

and microinvertebrate indicators should be counted in stream island development. The degree of vegetation development on stream islands is likely to be related to the amount of time the surface has been exposed above the seasonal low-water level, the position of the water table, the physical character of sediments and their stability, and the types of vegetation available for

TABLE 1 Stream island habitats.

Habitat type	Definition
Island Head	The starting point of an island within a stream. Typically, the surface material is rough, such as gravel and pebbles. Typically, this phenomenon is caused by erosion caused by high speed, although it can result in deposition due to a reverse current
Island Tail	The terminal point of an island located along the course of a river. The uppermost layer of the ground is composed of small-sized rocks and pebbles. Typically, the flow velocity or current is slower at the downstream side of a stream island compared to its upstream side
Island Edge	Any length of island edge that does not occur at the head or tail of an island but on a side of the island that is parallel to the flow and subject to steady and consistent flow forces. There is a wide variety of velocities and substrate kinds in between
Inner Island	The central area of the island that has permanent vegetation, the highest elevation, and is usually dry
Transitional Area	Area between the inner and outside island
Outside Island	A zone bordered by moving water. This location has sparse vegetation growth. The bank slope is usually rather level, with embedded sand and/or pebbles as the substrate

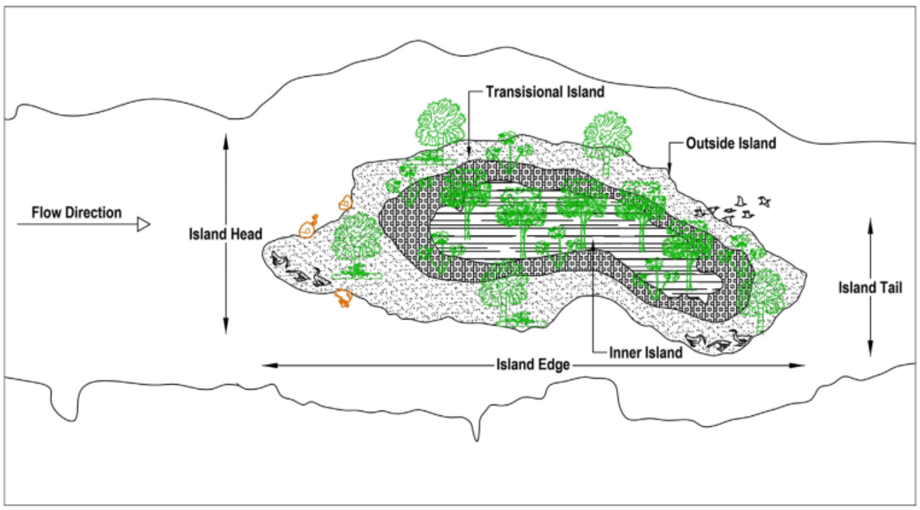

FIGURE 3
A typical design of habitat island types.

colonization. Depending on these factors, newly formed stream islands are progressively vegetated as they accrete vertically and laterally and it thus becomes difficult to define where an initial stream island becomes a complex stream island. There are multiple stream island habitat types based on a literature review (Table 1; Figure 3).

Results and discussion

This study proposes a conceptual framework for developing a stream island evaluation index for sustainable stream restoration projects. It seems essential that a serious attempt be made to design a system that can identify the overall stream island condition. Once a generalized stream island system is set up as a controlling framework, supplementary indexes for specific purposes and locations can be added.

A proposed methodology for a stream island index (SII)

This study provides a comprehensive methodological process for developing a conceptual framework of the Stream Island Index (SII) (Figure 4; Table 2). The purpose should be defined first. In constructing a conceptual framework, this study emphasizes the ecological aspect in addition to the hydraulics and geomorphology attributes. In the framework of a design and method study, it appears necessary to create and validate an index for measuring the parameters involved. A considerable effort was made to develop an index system capable of measuring the overall status of stream islands. In order to develop an index, first it is important to identify the concept or variable to measure and then the selected variables should be included in the developing index. Then, assign scores to each variable. The scores should be based on the relative importance

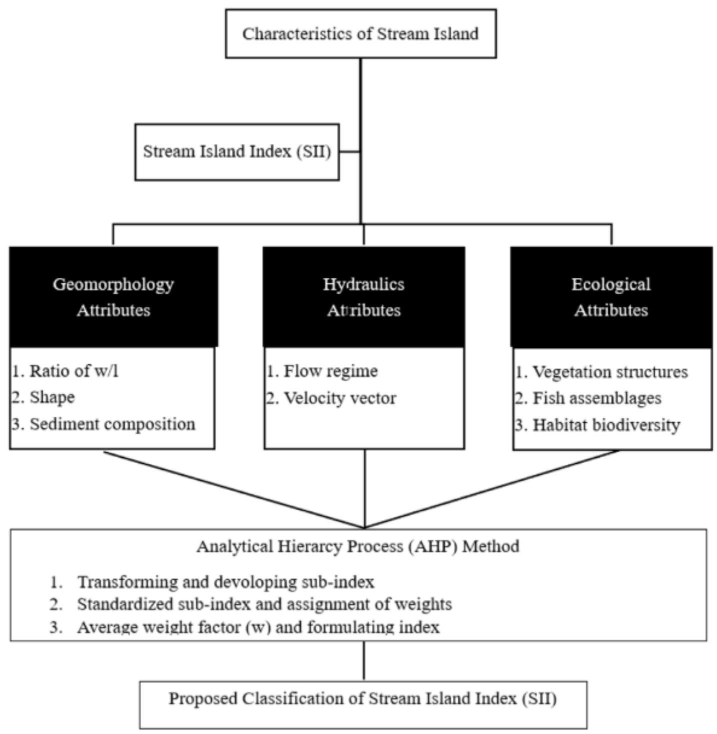

FIGURE 4
A conceptual framework of the Stream Island Index (SII).

TABLE 2 Methods for developing SII.

No.	Stages	Spatial data analysis	Interviews with experts	Field survey measurements
1	Screening and selecting attributes	●	●	●
2	Transforming and developing sub-indices	●		●
3	Assignment of weights	●	●	
4	Formulating an index	●		

of each variable to the concept or variable. This means the level or weight of importance is defined. The next step is to combine the scores of the individual variables to create the index. Detailed steps to create an index can be seen in Table 2. According to a previous study (Chavez and Alipaz, 2006), one common approach is to take the average of the scores of the individual variables. Therefore, in this offered analysis, an index formed by attributes meeting the above criteria could be universally applied, which would significantly increase their usefulness in establishing the development of the SII in a matrix scheme. Numerically, the SII can therefore be represented as:

$$SII = \sum_{i=1}^{n} w_i C_i \quad (1)$$

Where w_i is the average weight factor for the i^{th} parameter, and C_i is the standardized sub-index for the i^{th} parameter. Each quality value is then multiplied by an average weight factor, to take into account the relative contribution of each variable to the overall index.

This study also used the Analytical Hierarchy Process (AHP) method to process the development of the SII. In the early 1970s, Thomas L. Saaty invented a structured mathematics and psychology strategy for organizing and analyzing complex decisions by entailing and decomposing a complex decision into a set of criteria and subcriteria. This method allows the decision-maker to use a pairwise comparison matrix to analyze the relative value of each criterion and subcriterion. In the process of AHP, it is also necessary to have the weighted importance of each criterion and subcriterion, as well as

TABLE 3 Ratio scale used with 2, 4, 6, and 8 as the mid-values.

Ratio scale	Comparison between two factors
1	Equally important
3	Moderately important
5	Strongly important
7	Very strongly important
9	Extremely important

the overall ranking of the alternatives, in order to analyze and calculate it.

In the context of applying the AHP to the development of the SII, there are several stages for developing the SII (Table 2). First, spatial data should be generated by spatial analysis that reveal the geometric or geographic properties. Spatial data could use a computational model such as a Geographic Information System (GIS)-based model. This study proposes the rapid advancement of ArcGIS combined with Google-Earth software in spatial analyses of environmental stream island and habitat data triggered the need for change in methods of field survey measurements. Next, interviews with experts would be conducted in order to proceed with the AHP method. Expert judgments have often been used to acquire criteria weights when there is a lack of the required data (Reza et al., 2013) and software such as Expert Choice 11.0 is used to analyze multi-criterion decision-making problems based on the AHP approach. The experts thus evaluate the various criteria and alternatives using a numerical scale, as shown in Table 3. Overall, AHP is considered a robust decision-making tool in order to develop the SII. One restriction is that AHP is sensitive to the decision-maker's pairwise comparisons.

Concerning field survey measurements especially in fish assemblages indicators, sampling fish by using an electrofishing device is the appropriate method. This method identifies specific fish habitat use in streams. Moreover, the snorkeling method also can be used in clear stream conditions with some constraints such as the observer's ability to identify species and is characterized by spatial and temporal heterogeneity across various scales.

The understanding of SII in stream restoration projects

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Conclusion

In conclusion, it is important to have a comprehensive methodology as a template for physical habitat complexity assessment in stream restoration projects. This study introduced the Stream Island Index (SII) as a valuable tool for stream restoration practitioners or policymakers by using a single number to measure the quality of stream island habitats. Furthermore, the SII can be used for specific purposes in order to improve the quality and diversity of physical habitats in stream restoration projects. The SII can also be used to monitor and evaluate the stream restoration process in adaptive stream management strategies.

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Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

RT: Conceptualization, Writing–original draft.

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