Transfer of scientific knowledge among Great Lakes fishery professionals: how the Science Transfer Program is facilitating the transfer of scientific knowledge

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Executive Summary

The Great Lakes Fishery Commission (GLFC) is a committee comprised of fishery professionals from Canada and the United States, of varying occupation types whose mission is to the protect the Great Lakes Fishery. The commission develops scientific research programs that identify scientific information that protects and promotes the fishery shared by Canada and the United States. The Science Transfer Program (STP) is a program within the GLFC that focuses on the strives to improve the transfer of science from fishery professionals to policy/decision-makers. This report will identify trends in how fishery professionals interact with scientific information, how scientific information is used, the role STP plays in science transfer, views on the effectiveness of the current STP, and views on the overall transfer of science in the Great Lakes. The goal of this report is to provide the GLFC with recommendations to improve the efficacy of the STP and science transfer within the Great Lakes. The recommendations for the GLFC include continuing or increasing the meetings and utilizing digital tools to increase accessibility, having STP provide newsletters or briefings to fishery professionals to keep them updated

on research in the Great Lakes, and finally improve how science is presented to build trust between fishery professionals.

1.0 Introduction

The Great Lakes Fishery Commission (GLFC) was built to protect the Great Lakes Fishery that is shared by the United States and Canada through the development of research programs that provide the scientific knowledge necessary to protect and promote the fishery. In 1954, the Convention on the Great Lakes Fishery appointed the Great Lakes Fishery Commission with five main duties. These duties include creating and carrying out a research program between the United States and Canada that strives for sustaining the fish stocks of the Great Lakes, recommending courses of protection and improvement for fisheries, creating a sustainable control program for sea lamprey, and finally, publishing scientific information critical to protecting the fishery (Great Lakes Fishery Commission, n.d.). The Science Transfer Program is a program that has been developed by the Commission to make science more accessible to fishery management by identifying and delivering science and its products in a comprehensible manor to improve decision-making. With the duties of the commission in mind, the Science Transfer Program aims to the help the commission and its players make more strategic decisions in terms of the fishery and its needs through choosing projects that aim to make science more accessible to fishery managers. This program is intended to make the Great Lakes Fishery Commission more effective by bridging the gap between science and policy making, which allows for more informed decisions to be made with respect to fishery protection and development. This report will focus on the transfer of science within the GLFC network, what knowledge looks like, how new science is perceived by fishery professionals, and what the best methods of delivery are. Scientific knowledge can often be lost in translation when it comes to policy decision-making. The objective of this report is to provide the GLFC with relevant information that can support the planning and delivery of the Science Transfer Program. The report will discuss how Great Lakes fishery professionals use scientific information, their view on the GLFC Science Transfer Program and its efficacy, and how the program may improve science transfer efforts in the future.

2.0 Methods

This report was completed as part of an undergraduate directed studies and consists of research that is part of a broader study for the Great Lakes Fishery Commission's Science Transfer Program to understand the movement of scientific knowledge and information. Detailed methods are also described in Nguyen et al., 2020.

2.1 Interview Development

A 25-question interview was created consisting of open-ended and close-ended, Likert-type questions. Open-ended questions used for this report were created to gather information on each individual's background (i.e., where they work, the position they currently hold, how long they have held that position), understanding the characteristics of knowledge, individual's views on new science, best methods of communication, and opinions on current science transfer. The close-ended Likert-type question used for this report was answered on a 5-point scale to gather information on how frequently individuals went to various sources when seeking information relevant to their work (see Appendix A for full interview questions).

2.2 Data Collection

Interview data was provided by Brian Pentz in its raw form. From its raw form, the data was coded by Pentz using NVivo 12 (NVivo qualitative data analysis Software; QSR International Pty Ltd. Version 12, 2018). This report focused on questions 8 and 14-25 from the initial 25-question interview. For open-ended questions, the responses were assigned codes, similar codes were merged and then assigned thematic categories that best suited the code groups. Using the data from NVivo 12, the data was then separated into individual spread sheets based on question number. Open-ended questions were categorized based on occupational group. Groups consisted of managers, researchers, and assessment biologists. The thematic groups for questions 14-20 and 22-25 were re-categorized based on the raw data provided in the interview data spreadsheet provided by Pentz for the purposes of this report. Answers were analyzed by tallying the frequency of mentions for questions where participants could give more than one answer and tallied by number of individuals who provided each answer for questions where participants could only give one answer. The answers were categorized by occupation type. For close ended questions, answers were analyzed by taking the average of each answer and categorizing them based on occupation. Figures were created based on the tallied numbers.

3.0 Results

Table 1. Summary of individuals interviewed including, positions, departments they work for, average number of years in their position, direct involvement in decision-making, and if their role had a research component

Occupation Group (n=50)	Positions	Department	Average Years in Position	Direct involvement in decision-making	Research component to role
Manager (n=27)	Program manager, basin coordinator, program administrator, Great Lakes Fishery	Michigan Department of Natural Resources (DNR), Illinois DNR, Ontario Ministry of	8.7	Yes: 21 No: 6	Yes: 11 (answers included, not solely research, work collaboratively

	supervisor, Department of Natural Resources Lake manager, District supervisor, unit leader, unit supervisor, management biologist, habitat ecologist	Natural Resources and Forestry, Wisconsin DNR, New York State Environmental Conservation, Pennsylvania Fish and Boat Commission Lake Erie Research Unit, Minnesota DNR, Great Lakes Fishery Commission – Fish Management Program			with researchers) No: 14 (answers included, not directly, supervise research staff, administrative position)
Researcher (n= 12)	Fisheries research biologist, fisheries research scientist, manager of Lake Ontario management unit, lead fisheries biologist, research scientist, senior research biologist	US Fish and Wildlife Service, United States Geological Survey Great Lakes Science Center, Great Lakes Fishery Commission, Ontario Ministry of Natural Resources, Department of Fisheries and Oceans	16.3	Yes: 2, work in collaboration with decision-makers No: 10, however answered that they provided recommendat-ions and information to final decision makers	Yes: 12
Assessment Biologist (n=11)	Fisheries assessment biologist, assessment supervisor, senior aquatic biologist	Ontario Ministry of Natural Resources, Michigan Department of Natural Resources, Upper Great Lakes Management Unit, New York State Department of Environmental Conservation,	12.8	Yes: 10, in advisory capacity No: 1	Yes: 6 No: 5 (most answered their positions were assessment focused, or rarely assisted with research)

		Department of Fisheries and Oceans			

Table 2. Locations within the Great Lakes and/or St. Lawrence River regions where the work of managers, researchers, and assessment biologists takes place (n=49)

Body of Water	Managers	Researchers	Assessment biologists
Lake Erie	6	0	0
Lake Huron	5	3	1
Lake Michigan	9	1	0
Lake Ontario	2	1	4
Lake Superior	6	3	3
All Great Lakes	3	2	1
St. Lawrence River	1	1	0
Other	2	0	2

3.1 Great Lakes Fisheries Professionals Interactions with Scientific Information

3.1.1 When looking for scientific information, where do fishery professionals turn to first?

To understand the transfer of science and how knowledge gets from researchers to policy/decision-makers, it is important to know where fishery professionals look first when seeking out scientific information. Figure 1 shows the most common outlets provided by 49 of 50 fishery professionals who were asked where they go first for scientific information. The results show the number of times **managers** (n=27), **researchers** (n=12), and **assessment biologists** (n=10) mentioned each source in their interview answers (Figure 1).

Of the 27 individuals interviewed from **managerial positions**, turning to *colleagues and peers* first was mentioned 15 times, followed by *literature and journals* at 14 mentions (Figure 1). *Literature and journals* include peer reviewed articles and scientific journals. The *internet and/or online libraries* was mentioned seven times, followed by *google scholar* which was mentioned four times (Figure 1). Turning to *publication from the Great Lakes Fisheries Commission (GLFC)* and going to *external scientists and experts* were both mentioned twice in interviews (Figure 1). *Professional meetings* were the initial source of information by one individual. For **researchers** (n=12) turning to *literature/journals* first for scientific information was mentioned nine times (Figure 1). *External scientists and experts* had the

next highest frequency of mentions by researchers, at five (Figure 1). *Colleagues and peers*, *publications from the GLFC*, and the *internet and/or online library*, were each mentioned three times (Figure 1). *Google scholar* had the lowest frequency of mentions by researchers at two mentions (Figure 1). The source with the highest frequency of mentions by **assessment biologists** (n=10) was literature and journals at seven times (Figure 1). Turning to *colleagues and peers* as an initial source of information was mentioned four times, followed by the *internet and/or online libraries*, and *google scholar*, three times and once, respectively (Figure 1).

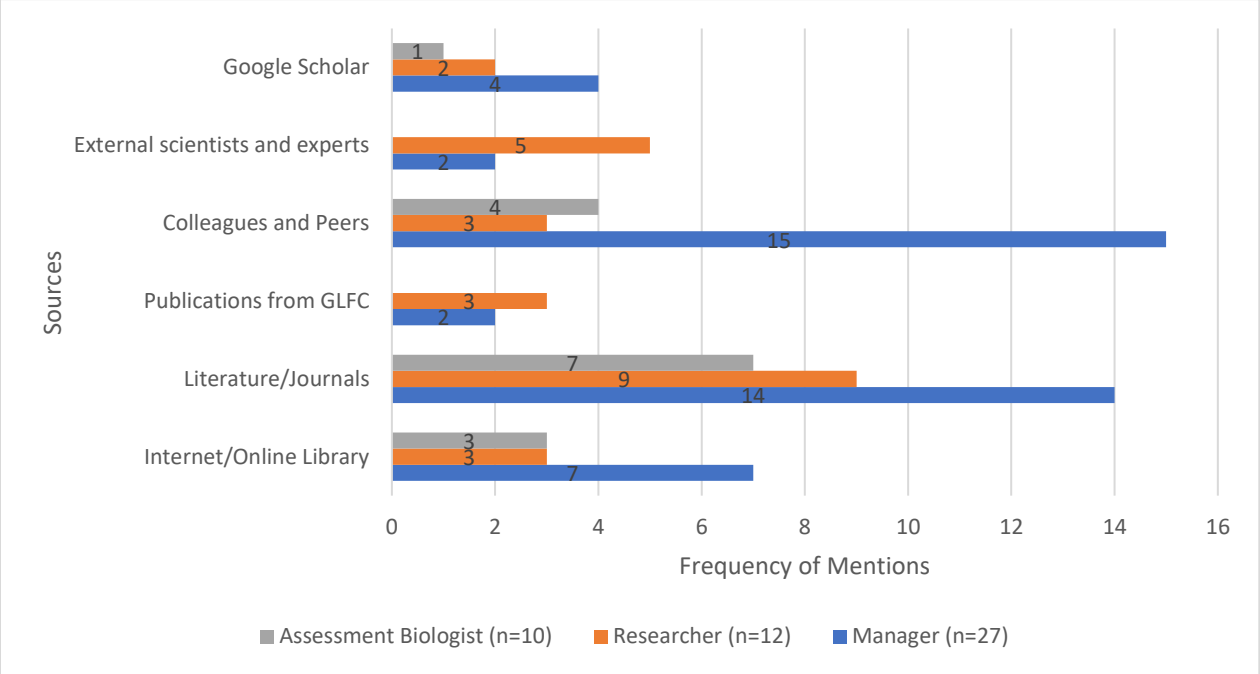

Figure 1. Frequency of mentions by managers, researchers, and assessment biologists on the source they first turn to for scientific information

3.1.2 What makes knowledge reliable? What criteria help fishery professionals believe or accept that the information is reliable?

Once fishery professionals have located scientific information the next step is to determine how reliable the information is. Forty-nine fishery professionals were asked to give their opinion on what makes knowledge reliable. Individuals were allowed to give more than one answer, with many citing multiple criteria of reliability. Of the individuals in **managerial positions** (n=27), *peer review* was mentioned 12 times, and the source individual 11 times (Figure 2). The source individual was described by fishery professionals as the specific person from which the information comes from (i.e., a colleague, an external scientist, or researcher). If that individual is of credible background, such that they are well known and have produced trustworthy research in the past, fishery professionals are more likely to consider them a reliable source of information. *Methods and repeatability* had a frequency of mentions of

seven and six, respectively by managers (Figure 2). *Methods* was described as the scientific approach that was taken to produce the information. If the methods used were rigorous and scientifically appropriate, managers would deem the information reliable. If the multiple researchers attempted the same research question and each produced the same results, the study has *repeatability*. The *institution as a source of information* was mentioned four times by managers (Figure 2). If the institution providing the information, such as a university or government department, is credible the information can be considered reliable. *Data quality* was mentioned four times by managers as being a criterion of reliability (Figure 2). *Data quality* refers to how the data was collected, if it was collected in a standardized fashion, and if it was peer reviewed. The *agency which funds the information* was mentioned once by managers as a criterion of reliability. For individuals in **research positions** (n=12), the criterion with the highest frequency of mentions was *peer review and study design*, both at seven mentions (Figure 2). *Methods and individuals as a source* were mentioned five times by researchers as being reliable sources (Figure 2). *Repeatability* was mentioned four times and the institution as a source was mentioned twice (Figure 2). The *quality of the data* as a source of reliability was mentioned once by researchers. The highest frequency of mentions by **assessment biologists** (n=10) was for *methods and peer review* as criterion of reliability at five mentions each (Figure 2). The *individual as a source* of reliability was mentioned four times, and *study design and repeatability* were mentioned three times (Figure 2). The *institution source* as a criterion of reliability was mentioned once and the *communication of findings* was mentioned once (Figure 2). The *communication of findings* refers to the clarity of the findings and whether the findings are stated clearly and can be understood.

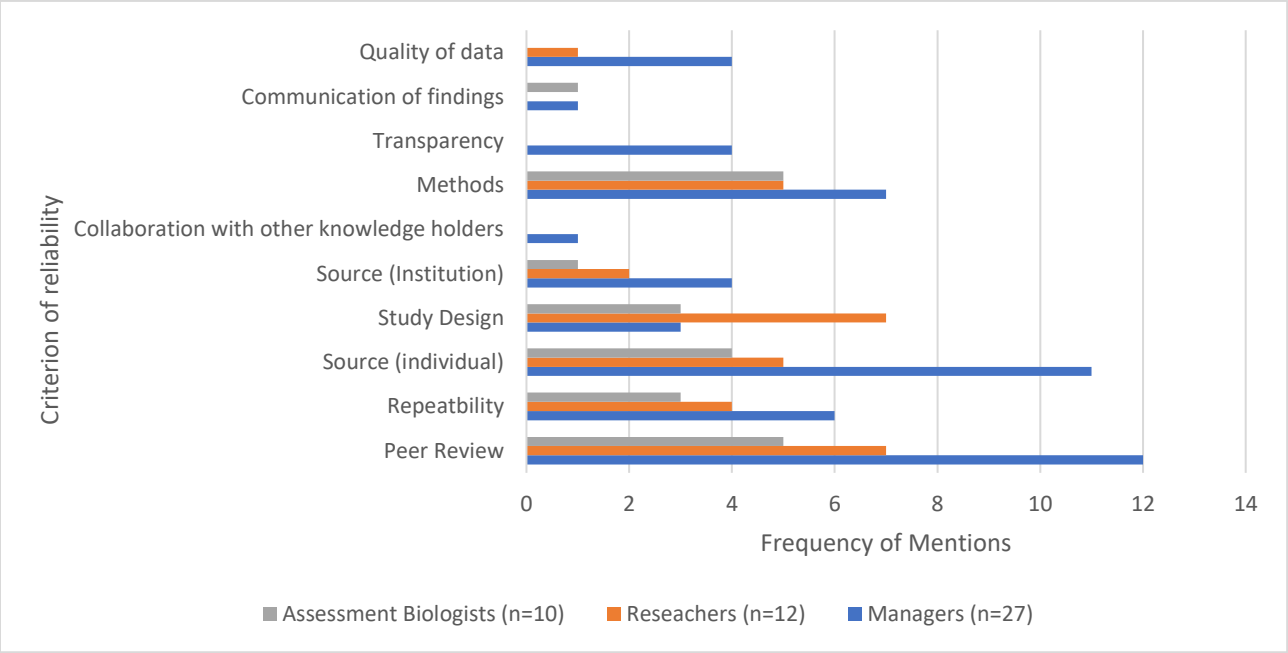

Figure 2. The frequency of times each criterion of reliability is mentioned by managers, researchers, and assessment biologists

3.1.3 How often do fishery professionals seek out information relevant to their work?

To get a better understanding of the availability of scientific knowledge it is important to ask how often fishery professionals will seek out information that is relevant to their work. Forty-nine fishery professionals were provided a list of sources and given a range of close-ended Likert-type answers which were made to describe how often they went to each source when looking for information relevant to their work. The range of answers were represented as 1 being never, 2 being less than monthly, 3 being monthly, 4 being weekly, and 5 being daily. Individuals were only able to provide one answer per source. The averages for each source were calculated for **managers**, **researchers**, and **assessment biologists** (Figure 3). For individuals in **managerial positions** (n=27), the average for *colleagues* was 4.55 (Figure 3). With 5 meaning they went to *colleagues* every day when seeking out information, 4.55 means that most managers went to their *colleagues* very frequently for information. The lowest average for managers was 2.7 for *reports from advocacy or other public interest groups* (Figure 3). With the value 2 representing less than monthly, managers seem to be less likely to turn to *reports from advocacy and public interest groups* for information relevant to their work. The highest average for **researchers** (n=12) is for *scientific reports or publications* at 4.45 (Figure 3). This includes peer-reviewed articles as well as publications from the Great Lakes Fishery Commission. The second highest average at 4.27 is for *colleagues* (Figure 3). This means that most researchers are turning to these sources of information more frequently than they are turning to *non-governmental websites*, which has an average of 2.62 (Figure 3). The highest average for **assessment biologists** (n=11) is shown for *colleagues* as a source when seeking out information (Figure 3), with *scientific reports or publications* behind it with an average of 4. This means that assessment biologists are frequently, between weekly and daily, turning to these sources for information relevant to their work. The sources with the lowest averages, both 2.45, for assessment biologists are *reports from advocacy or public interest groups, and listservs or automated alerts* (Figure 3). Listservs are computerized lists of email addresses kept by companies and organizations so they can send people emails with advertisements or announcement.

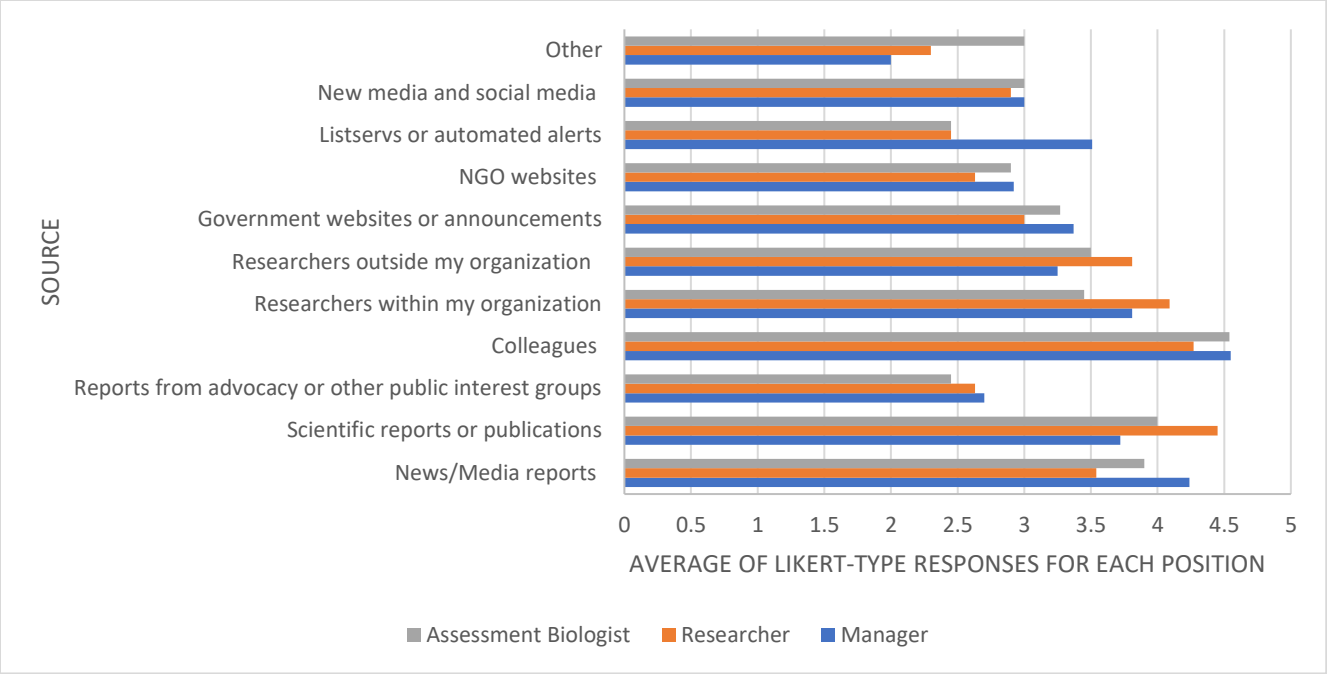

Figure 3. The average of each Likert-type responses from managers, researchers, and assessment biologists on how often they go to each source when looking for information relevant to their work (1 = never, 2 = less than monthly, 3 = monthly, 4 = weekly, 5 = daily)

3.2 Use of Research Findings

3.2.1 How accessible is research and scientific findings to fishery professionals?

Accessibility of research and scientific findings are crucial to the transfer of science. Forty-nine fishery professionals were asked to give their opinion on how accessible they believe research and scientific findings are. Figure 4 shows the number of individuals in **managerial, research and assessment biologist** positions and their opinions on the accessibility of research. Of the individuals surveyed in **managerial positions** (n=27), 12 said research is very accessible, nine said it was fairly accessible, three said it was not very accessible, and three said the accessibility needs improvement (Figure 4). Of the 12 individuals in **research positions** surveyed, nine answered very accessible, two answered fairly accessible, and one answered not very accessible (Figure 4). Of the answers given by researchers, there were four separate mentions of the inaccessibility of research for the general public. Managers provided varying answers as to why scientific findings are inaccessible. The main answers were that findings are difficult to locate unless the individual knows where to look, work is becoming more complex and difficult to work with even for professionals, and external information sometimes has paywalls. The consensus by managers who answered that the accessibility of research needs improvement said that in-person communication improves the accessibility of science. 11 **assessment biologists** were included in the survey, however only 10 were asked about research accessibility. Of the 10 assessment biologists surveyed, six said research and scientific findings are very accessible, three answered fairly

accessible, one answered not very accessible (Figure 4). There was one mention of the accessibility of research and scientific findings not being good for the public.

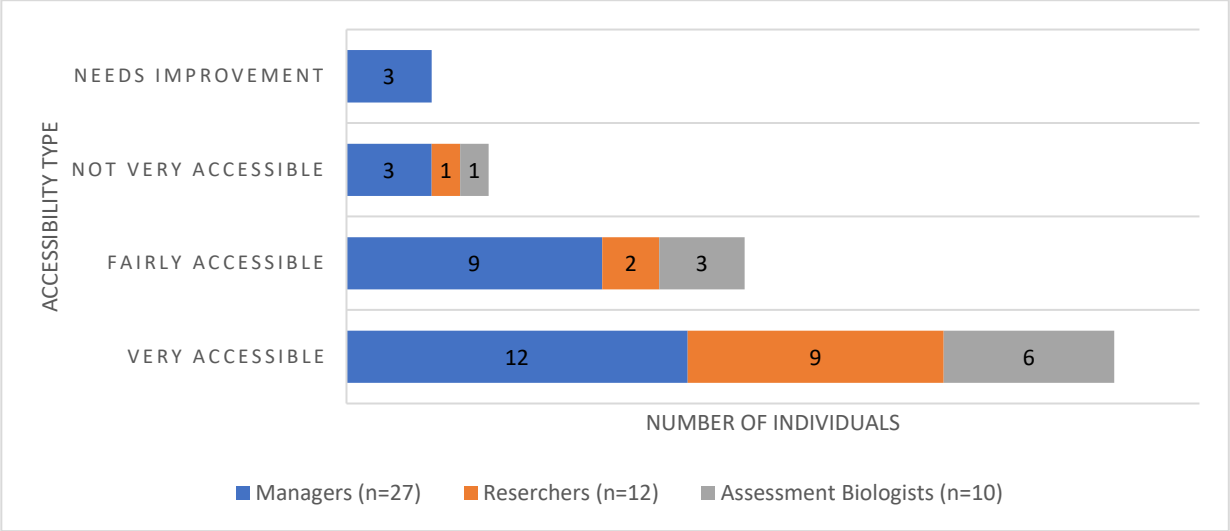

Figure 4. The number of individuals in each position and their opinion on the accessibility of research and scientific findings

3.2.2 What do fishery professionals think are barriers to using new scientific knowledge in fisheries management?

Understanding common barriers of accessing new scientific knowledge is helpful in the improvement of science transfer and helps to understand how to improve accessibility to scientific information. Figure 5 shows the frequency of times each barrier was mentioned by the 49 fishery professionals interviewed, separated by occupation type. The category with the highest frequency of mentions was change management, at four mentions by **managers** (n=25) (Figure 5). *Change management* is the management that must occur in response to resistance some might have towards new scientific knowledge. This often results in the need for convincing by others, typically by colleagues. The next highest frequency of mentions, at three mentions each, were *time constraints, accessibility, cost, political barriers, communication between actors, age-generational resistance, and understanding science/literature and limitations* (Figure 5). *Time constraints* are commonly described as the restrictions on time allowed by agencies to complete standardized assessments. *Accessibility* is whether the information can be found with relative ease. *Political barriers* sometimes include the inability of politics to keep up with the fast pace of science, it becomes difficult to create policies with the constantly changing field of science. Occasionally the goals of politics do not match the scientific findings. *Communication between actors* includes communication between stakeholders, managers, researchers, and the public. *Age-generational resistance* is common among older scientists who are more comfortable with older scientific knowledge and are resistant to accepting new knowledge. Having a *general*

understanding of the science and its limitations is a barrier to using new scientific knowledge as it may limit understanding its relevance and applicability. Less frequently mentioned barriers, at two mentions each included, *complexity/relevance, communication of findings, acceptance, and understanding the science and literature* (Figure 5). *Complexity and relevance* refer to how complex the knowledge is and if it is useful to the individual. *Communication of findings* means how clear the findings and results are and if it can be understood by everyone, not just the target audience. *Acceptance* refers to the acceptance of the scientific knowledge by stakeholders and managers. The barrier with the lowest frequency of mentions by managers, at one, was *data reliability*. *Data reliability* refers to the credibility of the data, and whether it was collected in a standardized way. The highest frequency of mentions by individuals in **research positions** (n=11) was *time constraints, and age-generational resistance*, at two mentions each. Barriers mentioned once by researchers included *change management, complexity/relevance, communication of findings, cost, and acceptance*. **Assessment biologists** (n=10) mentions the *cost* as being a barrier to using new scientific knowledge in fisheries management four times (Figure 5). The barrier with the next highest frequency of mentions was *communication between actors* at three mentions (Figure 5). It was then followed by *integration, change management, complexity/relevance, and understanding science/literature and limitations* at two mentions, respectively (Figure 5). *Integration* refers to how the new scientific knowledge can be integrated into existing knowledge. The barrier with the lowest frequency of mentions by assessment biologists were *communication of findings and acceptance* (Figure 5).

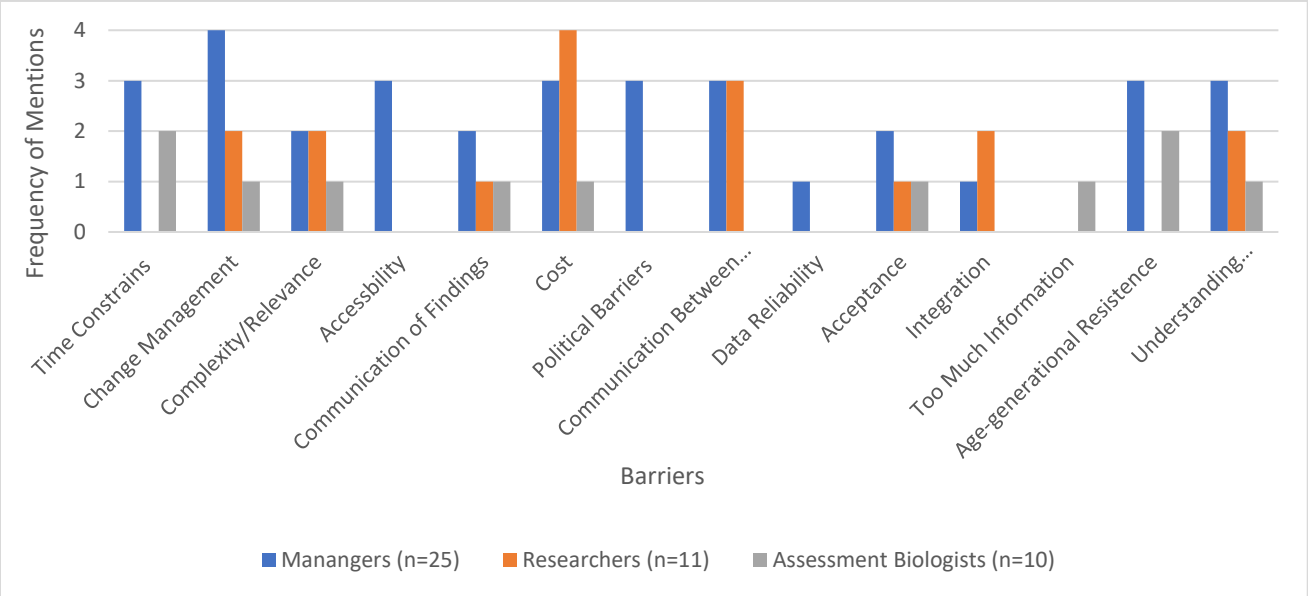

Figure 5. Frequency of mentions by managers, researchers, and assessment biologists on their opinions of barriers to using new scientific knowledge in fisheries management

3.2.3 What is your opinion on new science in general?

Individuals in the science field are constantly seeing science evolve and change. Forty-nine fishery professionals were asked what their opinion of new science is. Figure 6 shows the answers provided by individuals in **managerial**, **research** and **assessment positions**. The results display the number individuals who provided an opinion that matched the categories. Of the individuals in **managerial positions** (n=27) 19 said they were *supportive* of new science, three said they were *cautious*, three said it was *hard to keep up* with new science, and two said it *needed to be supported and applied to current scenarios* before they could support it (Figure 6). Of the answers provided by **researchers** (n=12), 10 said they were *supportive* of new science, one said it is *hard to keep up*, and one said new science *needs to be supported* (Figure 6). 10 individuals in **assessment biology positions** provided answers, nine said they were *supportive* of new science, and one said they were *cautious* (Figure 6).

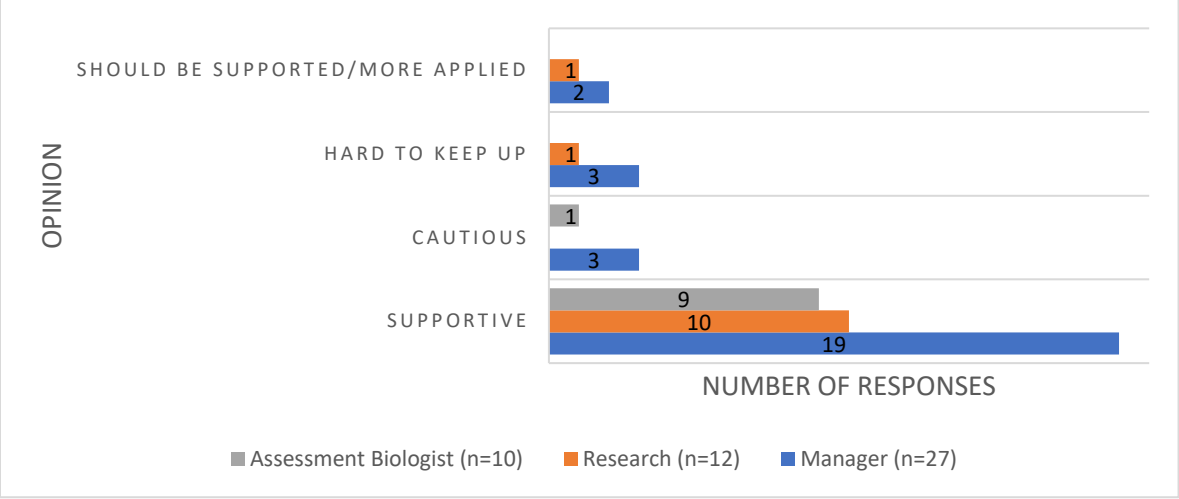

Figure 6. Number of responses by managers, researchers, and assessment biologists on their opinion of new science

3.3 Priority Research and the Role of STP

3.3.1 In your opinion, what are research topics of highest priority to fishery management in Lake X (their respective lakes) or Great Lakes Basin?

Table 3. Most commonly answered high priority research topics provided by managers, researchers, and assessment biologists – including the number of times they were mentioned

Position	Most common answers (number of times mentioned after initial mention)
Manager (n=27)	Invasive species (9), Climate change (3), Biotelemetry, eDNA, Barriers, Pathogens, Refined stock assessment tools, Habitat ecology/habitat mapping (2), Understanding stock recruitment relationships (1), Controlling sea lamprey (2), Ecosystems and trophic interactions (5), Managing stock populations, Population dynamics (2), Ecosystem energy transfer/dynamics (1), Lake trout population/mortality/restoration (1), Salmon bioenergetics,

	Migration, Recruitment (1), Fish passage, Predator-prey dynamics (2), Commercial fish harvest and stock assessment, Commercial bycatch, Habitat restoration, Implications of population/demographic change on environment, Nutrient inflow (1), Status of Cisco populations in Lake Superior (1), Asian carp productivity, Coordinated science and monitoring initiatives, Quadra/zebra mussels, Acoustic telemetry, Native species rehabilitation (1), Pre-diversity ecological implications of invasive species, Food web dynamics (1), Microbiome processes, Alternative control techniques, Minimizing risk to non-target species during lampricide treatment
Researcher (n=12)	Productivity change (2), Eutrophication (3), Prey populations, Salmon (1), Native species restoration (2), Prevent invasions, Ecosystem change/dynamics (4), Invasive species (3), Climate change (1), Cisco trends and recovery, Trophic level dynamics (1), Population dynamics, Sea Lamprey dynamics, Decline in fish forage, Better forecasting, Recruitment dynamics, Lake food web dynamics (1), Predator-prey dynamics (1), Energy pathways, Water quality, Habitat dynamics, Fisheries production, Sustainability, Land issues with fisheries
Assessment biologist (n=11)	Species at risk, Prey population status, Native species restoration (1), Invasive species (2), Adaptation to climate change (1), Population dynamics, Species biology, Recruitment, Food web dynamics, Ecological change, Chinook salmon, Water levels, Habitat data, Stock dynamics (1), Energy transfer, Cisco dynamics and ecology, Movement of Brook Trout in Lake Superior, Sea lamprey control management, Restocking/rehabilitating fish communities, Salmon prey abundance and population characteristics in Lake Ontario

3.3.2 Do fishery professionals believe the Science Transfer program has addressed these topics?

To ensure the STP is addressing the topics that are considered high priority by fishery professionals, 46 of the 50 fishery professionals were asked if they thought the STP had properly addressed the topics they though were high priority. Four individuals were not asked the question. Of the individuals in **managerial positions** (n=26), nine said *yes*, the STP has addressed the high priority topics in their opinion, seven answered *no*, seven answered that they *did not know*, and three answered *N/A* (Figure 7). The answer *N/A* includes individuals who were asked the question but did not provide an answer. Of the individuals in **research positions** (n=12), seven answered *yes*, one answered *no*, three answered that they *did not know*, and one answered *N/A* (Figure 7). Of the eight individuals in **assessment biology positions** who were asked if they thought the STP has addressed the high priority topics, four answered *yes*, and four did not provide an answer (Figure 7).

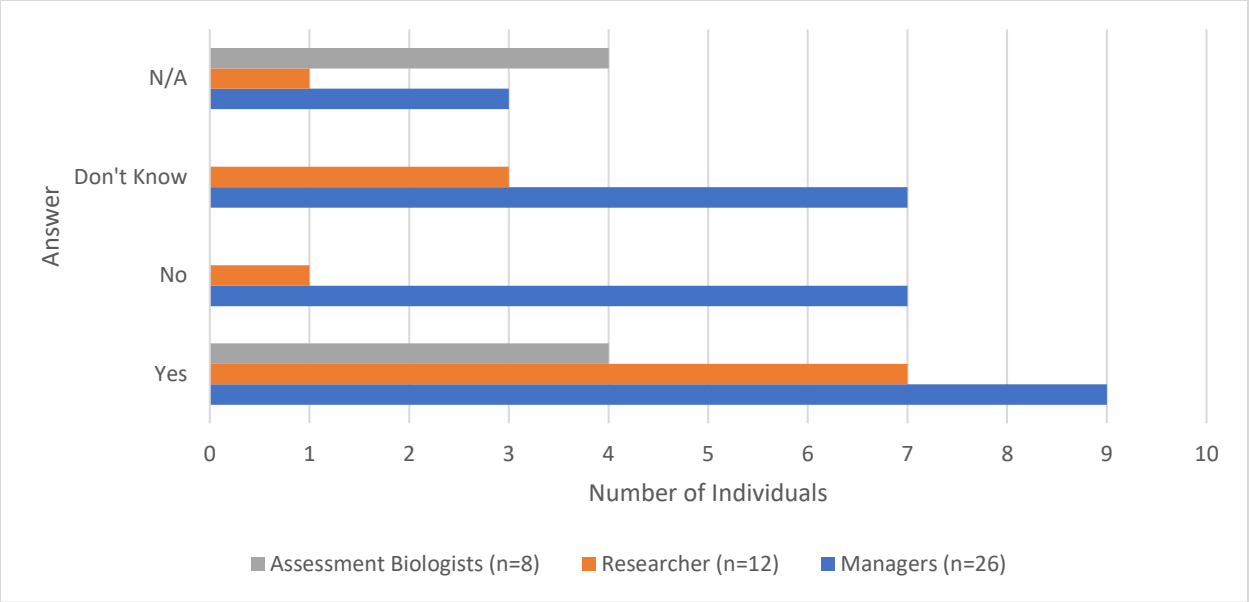

Figure 7. The number of individuals, separated by manager, researcher, and assessment biologist, and their opinion on the Science Transfer Program's address of high priority topics

3.4 *Perspectives on the Current Science Transfer Program*

3.4.1 What are fishery professional's opinion on the current science transfer of fisheries research in the Great Lakes Basin?

Forty-nine fishery professionals were asked for their opinion on the current science transfer of fisheries research in the Great Lakes Basin. Figure 8 shows the results of the survey and represents the number of answers for each opinion given by **managers** (n=27), **researchers** (n=12), and **assessment biologists** (n=11). Of the individuals in **managerial positions**, 10 said the current science transfer program is *effective*, 10 said it is *somewhat effective*, and seven said it *needs improvement* (Figure 8). Of the 12 individuals in **research positions**, six answered that the current science transfer program is *effective*, five answered that it is *somewhat effective*, and one answered that it *needs improvement* (Figure 8). Finally, eight **assessment biologists** (n=11) answered the current science transfer program is *effective*, two answered it is *somewhat effective*, and one answered that is *needs improvement* (Figure 8). Managers who gave mixed reviews on the current science transfer said that there is too much information for them to keep up with and that there are not enough forums to transfer the science effectively. Researchers and assessment biologists agree that there needs to be more done to let people know that the information exists because most times it is not well communicated and professionals are unaware of its existence.

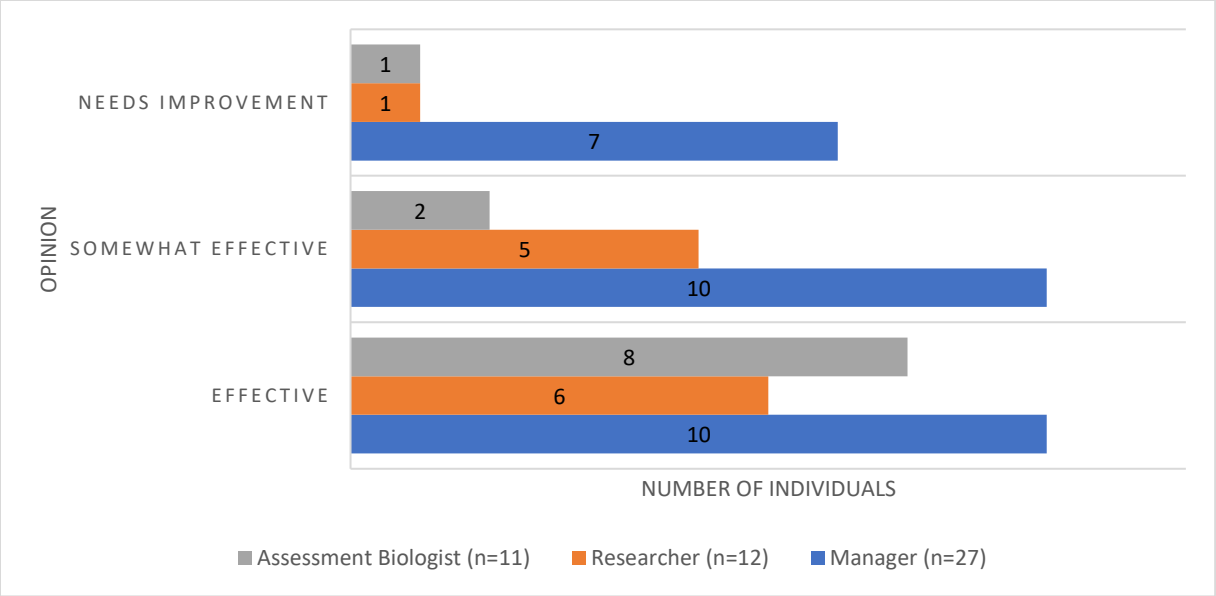

Figure 8. Number of individuals who provided their opinions on the current science transfer in the Great Lakes Basin

3.4.2 How effective and important to fishery professionals are the Lake Committee meetings in March of every year for the transfer of science to management?

It is important to know the opinion of fishery professionals on the efficacy and importance of the annual Lake Committee meetings as it lets the GLFC know if they should make any changes to the structure of the meetings or alter the focus on the meetings. Forty-nine fishery professionals were asked how effective and important they thought the Lake Committee meetings are to the transfer of science to management. Figure 9 shows the opinions of **managers** (n=27), **researchers** (n=12), and **assessment biologists** (n=10) and the number of individuals from each position who provided an answer. 19 **managers** said the meetings are *extremely important*, five said it was *important*, one said it was *somewhat important* and two said the meetings *need improvement* (Figure 9). In terms of improvement, managers believe that the Lake Committee meetings should increase the collaboration with the Tech Committee more as they work year-around to collect data and create figures, and they present their findings for the first time at Lake Committee meetings which has been found to be ineffective at transferring science to management. Of the individuals in **research positions**, eight said the meetings are *extremely important*, and four said they were just *important* (Figure 9). Of the **assessment biologists** asked, four said the meetings are *extremely important*, four said they were only just *important*, one said they are *somewhat important*, and one said it *needs improvement* (Figure 9).

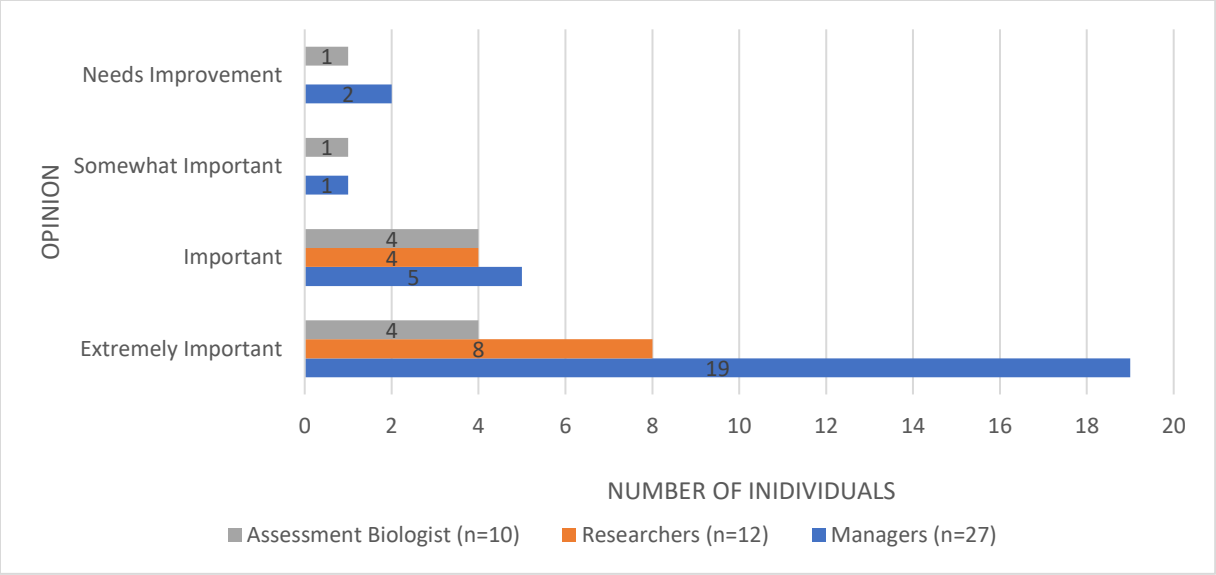

Figure 9. Number of managers, researchers, and assessment biologists and their opinion on the efficacy and importance of annual Lake Committee meetings

3.4.3 Are fishery professionals aware of Great Lakes Fishery Commission initiative to facilitate science?

Forty-nine fishery professionals were asked if they were aware of the GLFC initiative to facilitate science. Figure 10 represents the number of individuals from each occupation type if they were or were not aware of the GLFC initiative to facilitate science. Of the 27 individuals in **managerial positions,** 25 said they were *aware* of the initiative to facilitate science, and two said they were *not aware* (Figure 10). Of the individuals in **research positions** (n=12), 11 said they were *aware* of the initiative, and one said they were *not aware* (Figure 10). Of the **assessment biologists** (n=11), six said they were *aware* of the initiative and five said they were *not aware* (Figure 10).

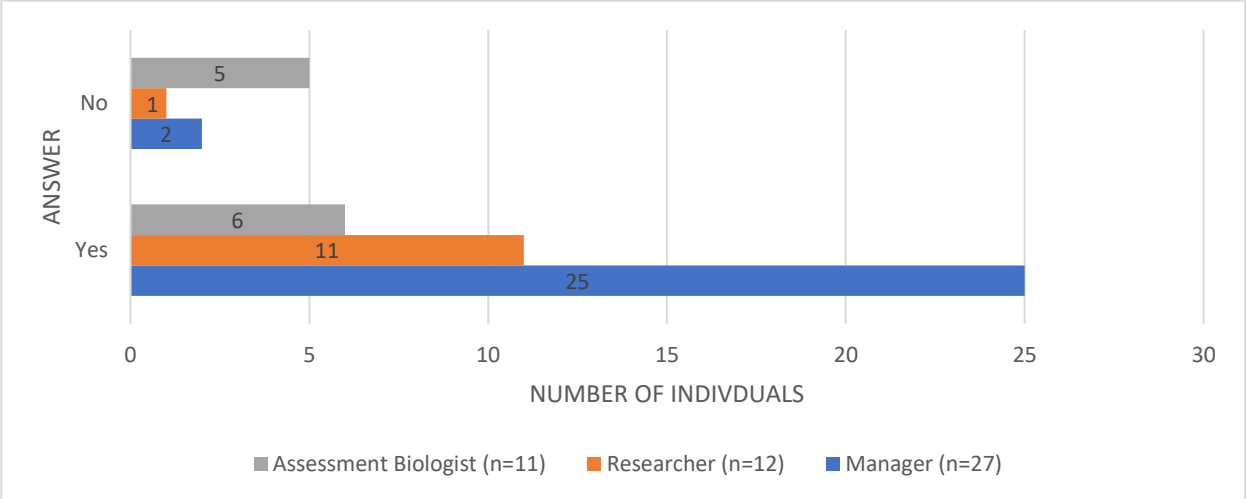

Figure 10a. Number of individuals in manager, research, and assessment biologist positions who answered if they are aware of the GLFC initiative to facilitate science or not

The individuals from Figure 10a (n=49) were then asked if they were aware of the Science Transfer Program or not. Figure 10b shows the same results for **manager**s (n=27) and **researchers** (n=12) in as the results in Figure 10a, however the results for **assessment biologists** (n=11) differ. Of the individuals in **assessment positions**, three said they were *aware* of the Science Transfer Program, and eight said they were *not aware* of the program (Figure 10b).

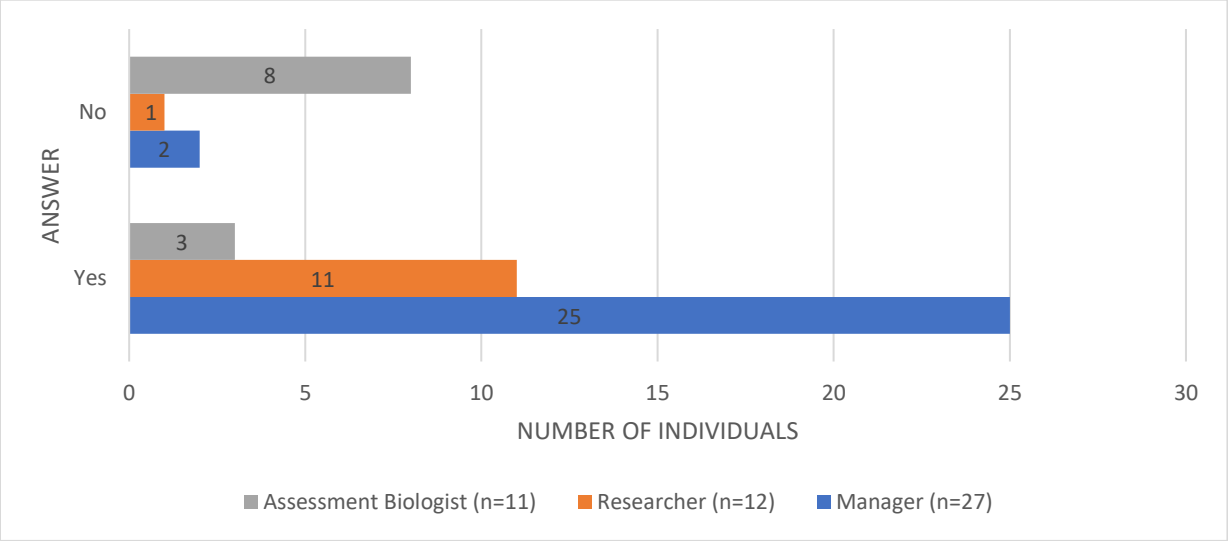

Figure 10b. Number of individuals in manager, research, and assessment biologist positions and whether they are or are not aware of the Science Transfer Program

3.5 Effectiveness of science transfer in Great Lakes

3.5.1 Fishery professional's opinion on whether the Science Transfer Program delivered research findings in an effective manner?

The GLFC must know how effective the delivery of research findings by the Science Transfer Program is in order to determine whether it is advantageous to the transfer of science to management. Of 50, only 46 fishery professionals were asked if they thought the Science Transfer Program was delivering researching findings in an effective manner. Four fishery professionals were not asked. Figure 11 shows the results of this question and represents the number of individuals from **managerial**, **research** and **assessment biologist** positions who provided an answer to the question. In Figure 11 the number of **managers** (n=26) who answered *yes*, the manner of delivery is effective was 13. Five individuals in **managerial positions** answered the delivery manner was *somewhat effective*, two answered that it was *not effective*, three answered that they *did not know*, and three were counted as *N/A* (Figure 11). Individuals who were counted as *N/A* did not provide an answer or their answer was noted as unclear. Of the individuals in **research positions** (n=12), seven answered *yes* to effective delivery of research findings, two answered that the delivery was *somewhat effective*, one answered that they *did not know*, and two were counted as *N/A* (Figure 11). Eight **assessment biologists** were asked their opinion on the

efficacy of the delivery manner by the STP and two said *yes, the delivery is effective*, one said it was *somewhat effective*, one said they *did not know*, *a*nd four were counted as *N/A* (Figure 11).

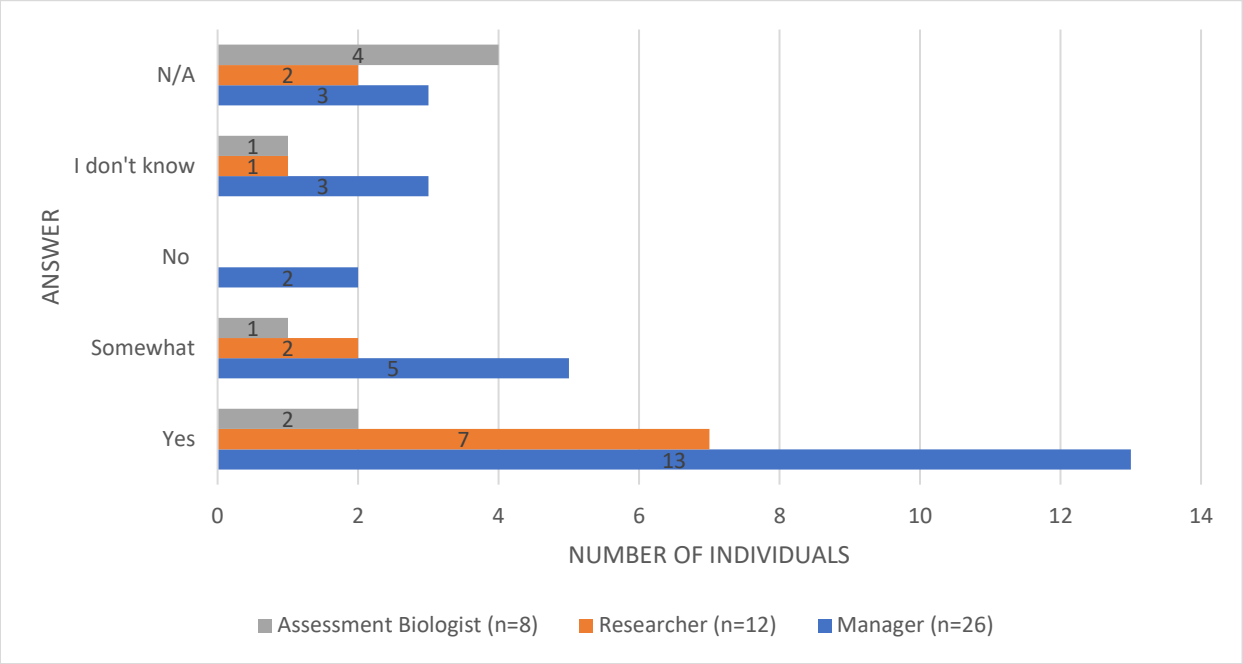

Figure 11. The number of individuals from manager, research, and assessment biology positions and their opinion on how effective the delivery of research findings is by the Science Transfer Program

3.5.2 What forms of communication do fishery professionals think are the most effective way for researchers to communicate study findings to managers/policy makers?

To ensure communication between scientists and managers/policy makers is effective, 49 of 50 fishery professionals were asked their opinion on what forms of communication would be the most effective way for researchers to communicate study findings to managers/policy makers. Figure 12 shows the types of communications and how often each type was mentioned by individuals in **managerial**, **research**, and **assessment biology** positions. **Managers** (n=27) mentioned *webinars* as a communication type the most frequently with 13 mentions, followed by *meetings* with 12 mentions (Figure 12). *Webinars* include Ted Talks, and the Lake Committee meetings which are sometimes filmed. *Meetings* include in person meetings such as Lake Committee meetings, technical meetings, and agency meetings such as the Department of Natural Resources meetings. *Workshops* were mentioned eight times by **managers** (Figure 12). Managers consider workshops to be effective because of the one-on-one interaction with researchers who conducted the studies. *Emails, conference calls, and presentations* were mentioned twice each by **managers** (Figure 12). *Blogs and social media* were mentioned once each, and the answer *all of the above* was given three times by **managers** (Figure 12). **Researchers** (n=12) mentioned *meetings* as a form of communication eight times, followed by *webinars*, at four mentions (Figure 12). There were two mentions of *workshops* being effective forms of communication, and *presentations and publications* were

both mentioned once each by **researchers** (Figure 12). The communication form with the highest frequency of mentions for **assessment biologists** (n=10) was *meetings*, at seven mentions (Figure 12). *Presentations* had the next highest frequency of mentions at three, followed by *literature, workshops, and conference calls* which were all mentioned once each. Literature includes journals, publications by the GLFC, and peer reviewed articles. The answer *all of the above*, was mentioned twice by **assessment biologists** (Figure 12).

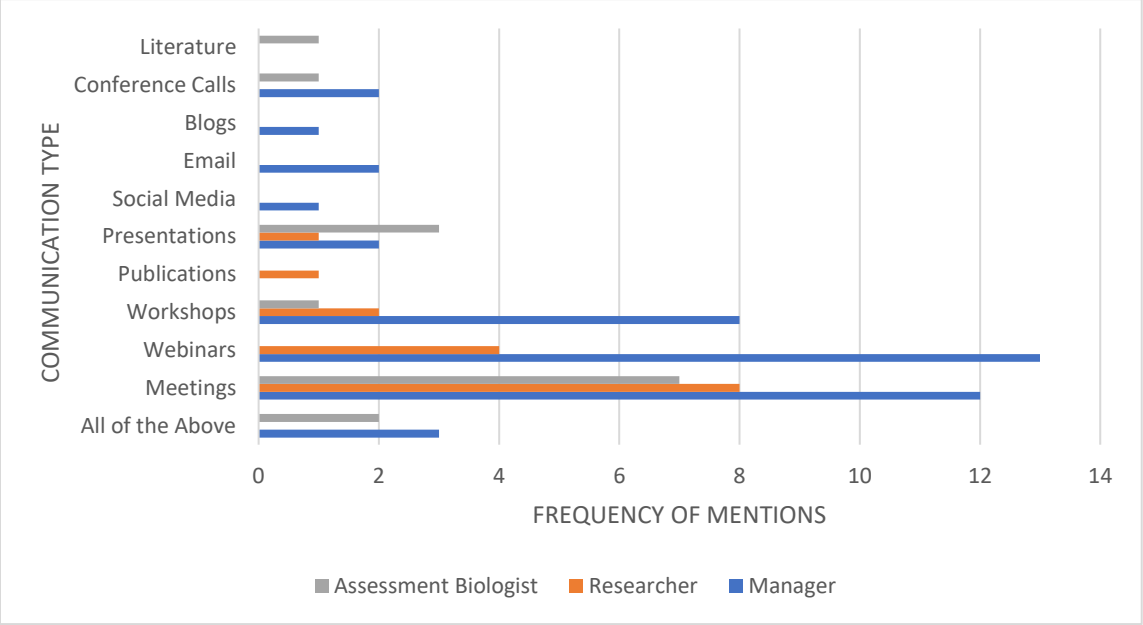

Figure 12. The frequency of mentions given by managers, researchers, and assessment biologists on the most effective forms of communication of research findings to managers/policy makers

4.0 Discussion

4.1 Interaction with scientific information: fishery professionals lean towards their peer network and the peer-reviewed literature

The results show that fishery professionals tend to interact with scientific information if they are accessible and peer-reviewed/trusted. In the case of those within the GLFC network, peer-reviewed literature is found to be accessed the most, is found to be most reliable, and tends to be the place that fishery professionals turn to first when looking for scientific information. Scientific literature and reports can be accessed easily by fishery professionals and are often peer reviewed which makes them more reliable too. While most study participants found research to be accessible, there were areas where research accessibility could use some improvement. This was mostly from the perspective of accessibility to the public. Participants mentioned that while it is accessible to individuals in their position, it needed improvement to be accessible to the public as well.

Managers are most likely to turn to their colleagues/peers when looking for scientific information because they are easily accessible, can be contacted quickly, and are seen as a reliable source of information. While managers will also look to literature and journals are more likely to use the information if it is peer-reviewed, the accessibility and reliability of their colleagues/peers increases the likelihood that they will be used as information sources. However, researchers and assessment biologists will tend to turn to literature and scientific journals because their focus of credibility mostly relies on whether the information is peer-reviewed and if the study that the information has come from was conducted well and thoroughly.

4.2 Using Scientific Findings: reported barriers tend to be resistant to change

The results show that the most fishery professionals are supportive of new science, however one of the most reported barriers to using new science is resistance and opposition to change. Research data showed that the resistance and opposition to new science comes mainly from older professionals, in both managerial and assessment biologist positions in the field who tend to be too used to using previous knowledge. Research data showed that while most study participants were supportive of new information, they delt with resistance to change from managers and decision-makers who are unwilling to entertain new ideas and information because it is difficult to keep up with all the information being released, and they require additional support/application of the information in order for them to accept it and incorporate it into decision-making. While resistance to change was a major barrier reported by all occupation levels, research data and results showed that there was a trend among study participants who reported that budgetary restraints and the cost of new equipment was a barrier to using new scientific information. Research data showed that the process of developing new scientific information is costly and oftentimes researchers/assessment biologists do not have adequate funding to use the new technology that is required to gather the information.

4.3 The Science Transfer Program: professionals support the current program, but unique topics of interest are overlooked

Current science transfer is generally seen as effective by researchers and assessment biologists however the results show that the answers were split between managers. The research data showed that researchers and assessment biologists thought that the STP has been a good sounding board for ideas surrounding high priority topics such as productivity change, native species restoration, invasive species, and ecosystem dynamics, and has done well with bringing together professionals of similar interest to facilitate the transfer of science relating to these high priority topics. However, the research data has also showed that within the GLFC, managers have varying answers to the efficacy of the STP's address of

high priority topics. Research data and the results show a trend that the managers who answered no/don't know to whether the STP has addressed the topics they view as high priority simply were not aware of any attempt by the STP to address their specific topics of interest. However, managers who answered yes had topics of interest that were more common among managers, such as invasive species and ecosystem dynamics.

Some managers said that current science transfer is effective because of collaborations between managers and researchers and that it can help to sift through excess information. However, others found that there is too much information and that it is not only hard to keep up and know about this information, but that there is often reproduction of work because researchers are unaware that the work is already being done. Some managers also mentioned that political pushback is also a factor too in the current science transfer and that science cannot be objectively transferred to professionals if there is a political agenda.

4.4 Lake Committee Meetings are effective to science transfer and professionals are generally aware of science transfer within the GLFC and STP

The general trend in the results was that most fishery professionals prefer in-person meetings such as committee meetings and workshops as forms of communication. Specifically, managers find the annual Lake Committee meetings to be important to the transfer of science because they like the face-to-face interactions in the meetings. Research data showed that Lake Committee meetings are important to managers because they provide them with knowledge and information they can use during decision-making. While researchers and assessment biologists found the Lake Committee meetings can be useful, many said that they get most of their information from technical meetings and collaborations with other researchers and scientists before the meetings occur. Researchers believe that in some instances the meetings are not useful to researchers or assessment biologists because everyone in the room already knows the information unless they are a manager and were not involved in the production of the knowledge. The results show that in addition to the Lake Committee meetings receiving an overall positive reaction from study participants, the same is true for the delivery of research by the STP. While most fishery professionals were aware of the GLFC's initiative to transfer science and the existence of the STP, the number of managers who found the delivery of research by the STP to be effective and the number who did not find the delivery method to be effective or did not know, was split. The research data shows that unless they answered explicitly yes to whether the STP was effective in their delivery of researching findings, managers were generally unaware of any efforts made by GLFC to use the STP to transfer science.

4.5 Recommendations

Below are recommendations for greater science transfer based on the results of this study:

1. Continue or increase meetings and leverage digital tools to increase accessibility and reach of professionals:

The results show that meetings are highly favoured by most of the fishery professionals. This is because professionals like the face-to-face contact that comes with attending meetings. It is easier for them to create contacts and network with other professionals in the field at in-person meetings. Webinars were highly cited by managers because it is often difficult for people to attend meetings that are in other cities. My recommendation would be to have more frequent meetings throughout the year, so managers and policy makers are able to stay up to date with the research that is being conducted. I would also recommend that these meetings have an option of attending via Zoom or other video conferencing device, so that managers who are not able to attend the meetings in person are still able to attend and interact with researchers who are presenting.

2. STP can provide regular updates via newsletter or briefings to fishery professionals on what kind of research is ongoing in the Great Lakes:

Another recommendation for the Science Transfer Program to improve their current science transfer practices is to create a newsletter or a briefing where they can update fishery professionals on what kind of research is being conducted throughout the Great Lakes to ensure that professionals can stay updated on research. Often, managers say they cannot keep up with the amount of knowledge available to them and that there needs to be a better way of letting managers known about information. Therefore, a newsletter or a monthly publication that outlines what is being done would be beneficial to fishery professionals and result in more efficient science transfer.

3. Improve way we present science where building trust is a core part of it:

Since the most frequently mentioned barrier by managers is change management, and age-generational resistance is highly cited by both assessment biologists and managers, it is important to improve the way that new science is presented to individuals in these positions so they can have confidence in the new emerging science, and they can keep up with the knowledge being published. The final recommendation I will give is for the Science Transfer Program to look into having more workshops where managers, researchers, and assessment biologists can have one-on-one interactions in-person and can ask questions that will ease their reluctance to using new science. This will build trust between the individuals and new science and decrease the resistance that has created a barrier in the use of new scientific knowledge.

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Nguyen, V. M., Delle Palme, C., Pentz, B., Vandergroot, C. S., Krueger, C. C., Young, N., Cooke, S. J. (2020). Overcoming barriers to transfer of scientific knowledge: integrating biotelemetry into fisheries management in the Laurentian Great Lakes. *Socio-Ecological Practice Research*, *3*(1), 17–36. https://doi.org/10.1007/s42532-020-00069-w

Appendix A

Part 1: BACKGROUND

1. Please tell me a bit about your current position and responsibilities?
2. How long have you held this position? [Probe for past experience if relevant]
3. Please tell me about your educational background (i.e., were you trained in management or in the natural sciences?)
4. Are you directly involved in fisheries management decision-making? [If yes, in what capacity? If no, can you briefly describe how your work relates to fishery management decision-making](Ask about whether they consult, advise ir how they might interact with managers during the decision making process)
5. Does your role involve a research component?
6. Does your work take place in any particular lake, river, or region? Please specify.

PART 2: KNOWLEDGE SEEKING HABITS AND PRACTICES OF USERS OF SCIENCE

7. Do you seek out new science regarding fisheries management within the Great Lakes?

8. How often do you seek out scientific information relevant to your work from the following sources? [For colleagues and researchers, ask and record "How do you typically communicate with them?" e.g, telephone, email, in person]

	Daily	Weekly	Monthly	Less than monthly	Never
News/Media reports (print, television, radio, press releases, etc.)	○	○	○	○	○
Scientific reports or publications	○	○	○	○	○
Reports from advocacy or other public interest groups	○	○	○	○	○
Colleagues (other managers I work with)	○	○	○	○	○
Researchers within my organization	○	○	○	○	○
Researchers outside my organization (e.g., universities, other agencies, private)	○	○	○	○	○
Government websites or announcements	○	○	○	○	○
Websites belonging to non-government organizations	○	○	○	○	○

Listservs or automated alerts	○	○	○	○	○
New media and social media (blogs, podcasts, Facebook, Twitter, LinkedIn, etc.)	○	○	○	○	○
Other, please specify... _____	○	○	○	○	○
Other, please specify... _____	○	○	○	○	○

9. In the past 5years, have you collaborated with investigators on a research project?
    a. [If yes] were the Researchers Internal or a part of your organization? [If they answer not internal] Where were the researchers from? (Probe: agency, university, consulting, other)
    b. How was your experience collaborating with investigators? [Probe: positive? What made it positive? Negative? Challenging? What were some challenges? Easy? What made it easy?]

    c. [If no] Why not? [Probe: Was this because of a lack of opportunity collaborate (not involved in projects)? Of interest? Not part of job duties/ requirements?] [Intentionally vague so as not to imply failure or deficiency]

    d. What advice would you give [fishery] scientists/researchers about their research [Probe: What are scientists/researchers doing right? What are they doing wrong?]
    e. How effective are researchers at communicating their findings?

PART 3: UNDERSTANDING THE PERCEPTIONS THAT GREAT LAKES MANAGERS HAVE ON TELEMETRY SCIENCE

10. How familiar are you with biotelemetry science? (Fish tagging and tracking)
    A. Have you used biotelemetry in your own work? If so, in what context (How did you use it?)
11. Do you think biotelemetry could play a role in managing fisheries in the Great Lakes? A. If yes, how important is biotelemetry information in relation to other kinds of information in your decision making?
    B. What are the strengths of biotelemetry? C. Are there special or unique types of information that biotelemetry can provide to management?
    D. What are the limitations of biotelemetry? E. What can't telemetry do?
    F. What are the ecological and political barriers to its implementation?
12. Are you aware of any networks/ researchers that are conducting biotelemetry projects? [If yes, probe and have them name specific programs or efforts that do this.]
    [If they don't name GLATOS specifically] – Are you aware of the GLATOS – Great Lakes Acoustic Telemetry Observation System?

13. Please indicate the extent to which you agree or disagree with the following statements [Interviewer: be sure to record explanations. Ask for elaborations]. Response options: strongly agree, disagree, neither agree or disagree, agree, strongly agree, don't know.

    a. Biotelemetry provides reliable information about fish behaviours in the Great Lakes
    b. Biotelemetry provides reliable information about ecosystems in the Great Lakes
    c. The handling involved with inserting or attaching telemetry transmitters onto fish make the data generated by biotelemetry unreliable
    d. Biotelemetry research is cost-effective
    e. Biotelemetry provides us with information we wouldn't otherwise have from other sources or studies
    f. Biotelemetry should play a more standard role in fishery management than it currently does
    g.
    h. Biotelemetry findings should be taken with a grain of salt
    i. Biotelemetry data and findings should only be used by managers after being subject to a peer-review process
    j. Biotelemetry data on fish movements and behaviour should be freely available to anyone who wants it
    k. Integrating new knowledge emanating from biotelemetry into management is difficult.
    l. [For managers only]: I would be more comfortable using biotelemetry data and findings if the research was being conducted by researchers within my agency [?]

PART 4: UNDERSTANDING VARIABLES THAT INFLUENCE THE MOVEMENT OF NEW SCIENCE INTO PRACTICE

14. In your opinion, what makes knowledge reliable? What criteria help you to believe or accept that the information is reliable?
15. In your opinion, how accessible is research and scientific findings?
16. When looking for scientific information, where do you turn first?
17. In your experience, what do you think are barriers to using new scientific knowledge in fisheries management?
18. Overall, what is your opinion on new science in general?
19. What is your opinion of the current science transfer of fisheries research in the Great Lakes basin? [Prompt: do you believe it is effective? How so? If not, why not?]
20. How effective and how important to you are the Lake Committee meetings in March of every year for the transfer of science to management?
21. Are you aware of Great Lakes Fishery Commission initiatives to facilitate science transfer? [If yes, probe and have them name specific programs or efforts that do this.]
    a. [If they don't name the Science Transfer Program specifically] – Are you aware of the Science Transfer Program?
22. In your opinion, what are research topics of highest priority to fishery management in Lake X OR Great Lakes Basin?
23. [If applicable] Do you believe the Science Transfer Program has addressed these topics?
24. [If applicable] In your opinion, has the Science Transfer program delivered research findings in an effective manner?

    a. If yes, provide example?
    b. If no, why do you believe they have not?
25. What forms of communication (webinars, workshops, lake specific technical committees, scientific meetings, etc) do you think would be the most effective way for researchers to communicate study findings to managers/ policy makers?

Appendix B

Table 1. Summary of individuals interviewed including, positions, departments they work for, average number of years in their position, direct involvement in decision-making, and if their role had a research component

Occupation Group (n=50)	Positions	Department	Average Years in Position	Direct involvement in decision-making	Research component to role
Manager (n=27)	Program manager, basin coordinator, program administrator, Great Lakes Fishery supervisor, Department of Natural Resources Lake manager, District supervisor, unit leader, unit supervisor, management biologist, habitat ecologist	Michigan Department of Natural Resources (DNR), Illinois DNR, Ontario Ministry of Natural Resources and Forestry, Wisconsin DNR, New York State Environmental Conservation, Pennsylvania Fish and Boat Commission Lake Erie Research Unit, Minnesota DNR, Great Lakes Fishery Commission – Fish Management Program	8.7	Yes: 21 No: 6	Yes: 11 (answers included, not solely research, work collaboratively with researchers) No: 14 (answers included, not directly, supervise research staff, administrative position)
Researcher (n= 12)	Fisheries research biologist, fisheries research scientist, manager of Lake Ontario management unit, lead fisheries biologist, research scientist,	US Fish and Wildlife Service, United States Geological Survey Great Lakes Science Center, Great Lakes Fishery Commission, Ontario Ministry of Natural Resources, Department of	16.3	Yes: 2, work in collaboration with decision-makers No: 10, however answered that they provided recommendat-ions and information to final decision makers	Yes: 12

	senior research biologist	Fisheries and Oceans			
Assessment Biologist (n=11)	Fisheries assessment biologist, assessment supervisor, senior aquatic biologist	Ontario Ministry of Natural Resources, Michigan Department of Natural Resources, Upper Great Lakes Management Unit, New York State Department of Environmental Conservation, Department of Fisheries and Oceans	12.8	Yes: 10, in advisory capacity No: 1	Yes: 6 No: 5 (most answered their positions were assessment focused, or rarely assisted with research)

Table 2. Locations within the Great Lakes and/or St. Lawrence River regions where the work of managers, researchers, and assessment biologists takes place (n=49)

Body of Water	Managers	Researchers	Assessment biologists
Lake Erie	6	0	0
Lake Huron	5	3	1
Lake Michigan	9	1	0
Lake Ontario	2	1	4
Lake Superior	6	3	3
All Great Lakes	3	2	1
St. Lawrence River	1	1	0
Other	2	0	2

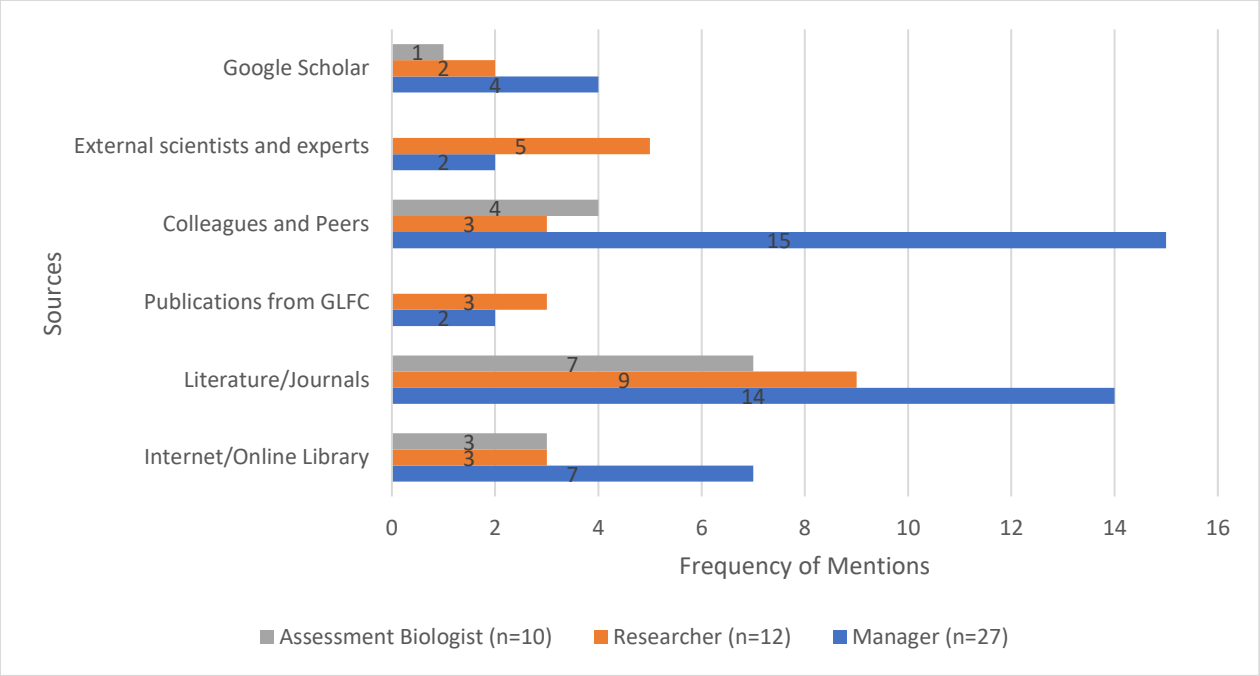

Figure 1. Frequency of mentions by managers, researchers, and assessment biologists on the source they first turn to for scientific information

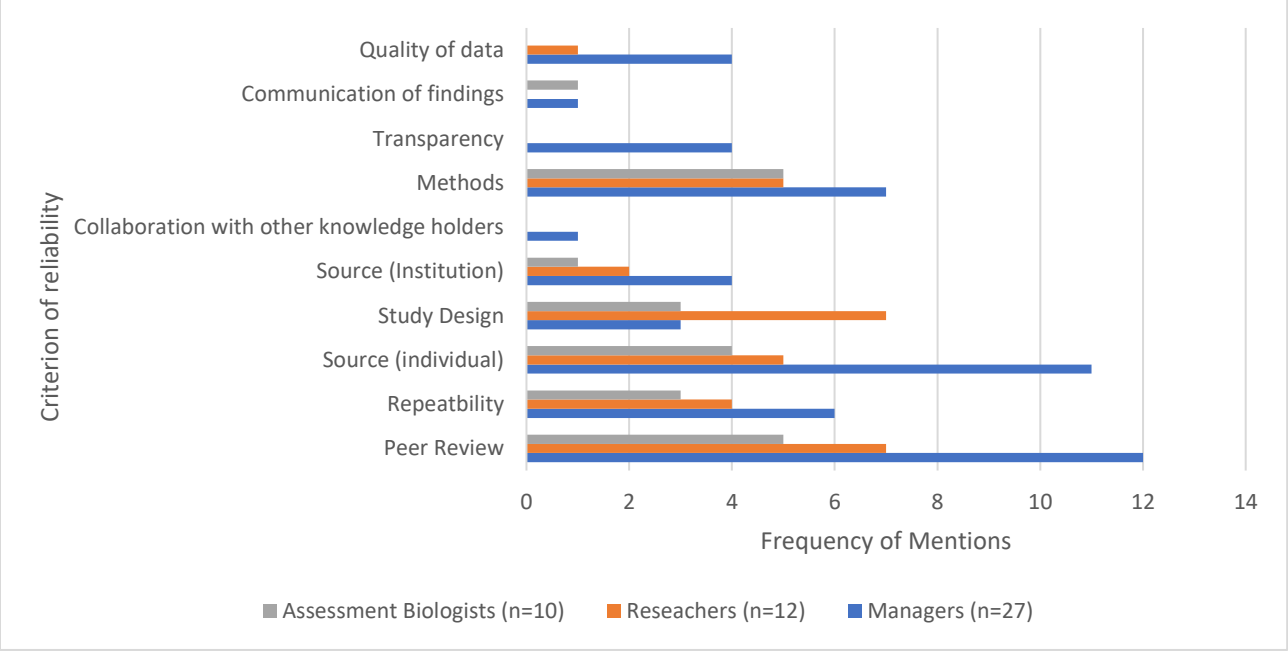

Figure 2. The frequency of times each criterion of reliability is mentioned by managers, researchers, and assessment biologists

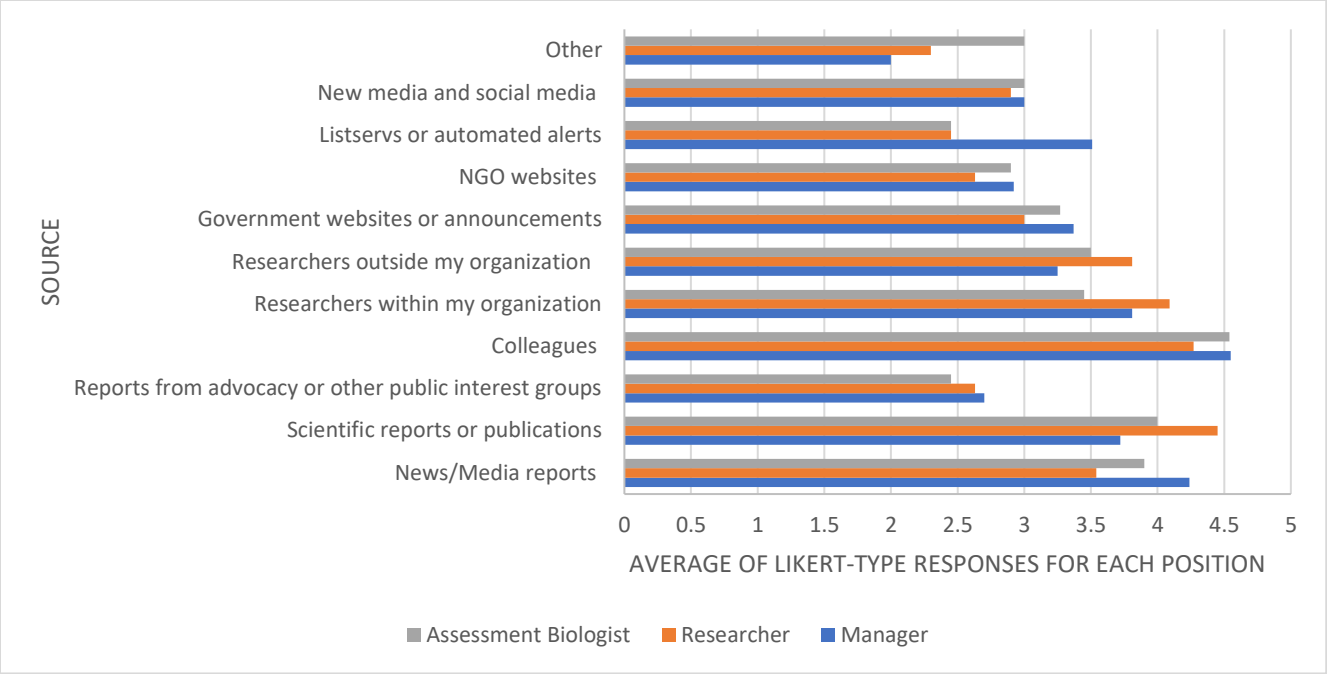

Figure 3. The average of each Likert-type respons from managers, researchers, and assessment biologists on how often they go to each source when looking for information relevant to their work (1 = never, 2 = less than monthly, 3 = monthly, 4 = weekly, 5 = daily)

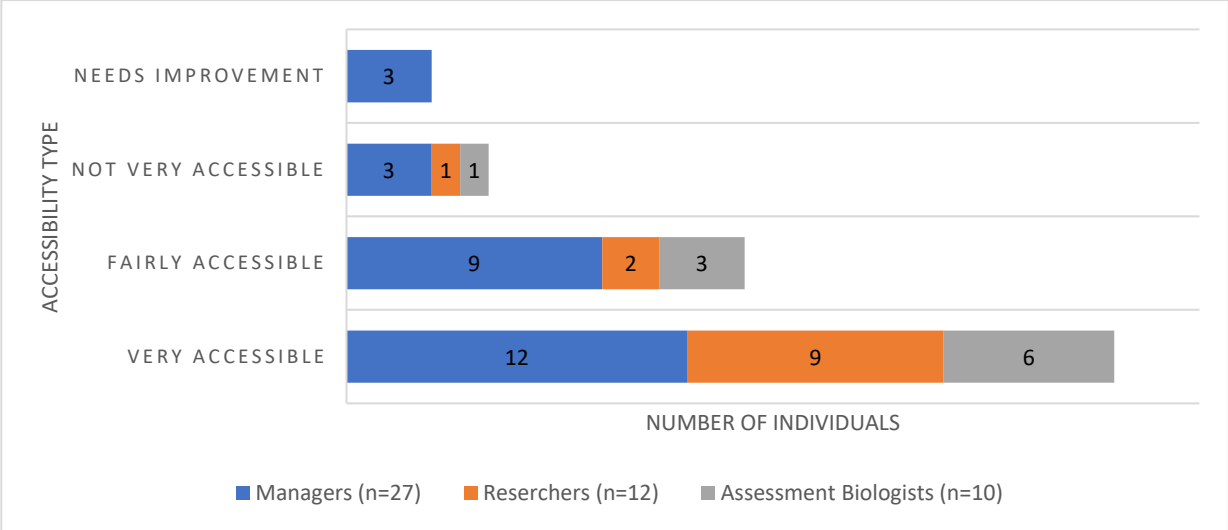

Figure 4. The number of individuals in each position and their opinion on the accessibility of research and scientific findings

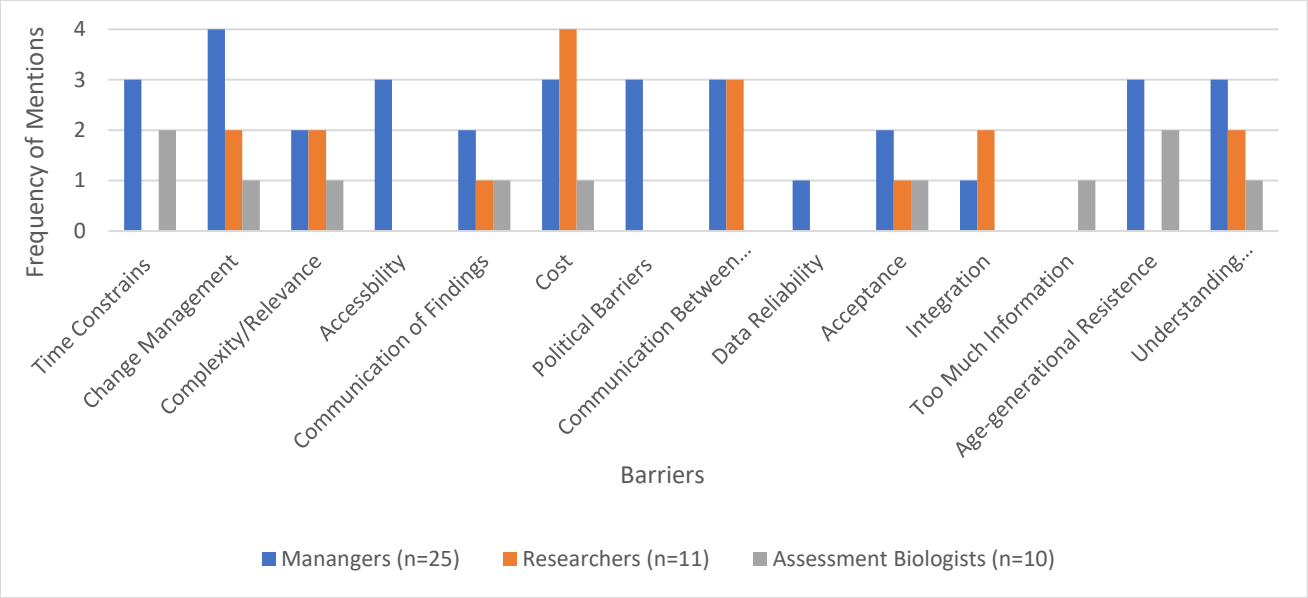

Figure 5. Frequency of mentions by managers, researchers, and assessment biologists on their opinions of barriers to using new scientific knowledge in fisheries management

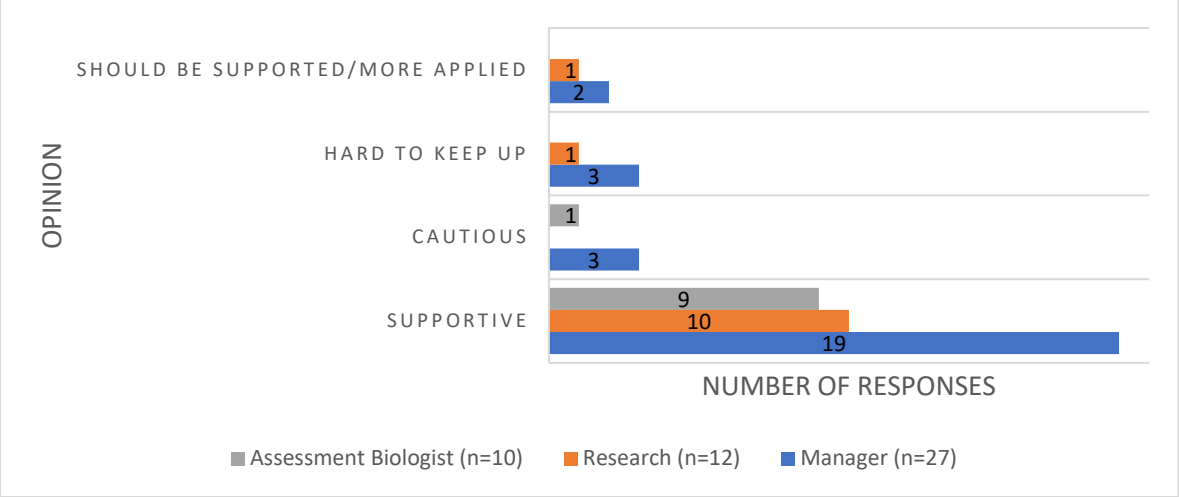

Figure 6. Number of responses by managers, researchers, and assessment biologists on their opinion of new science

Table 3. Most commonly answered high priority research topics provided by managers, researchers, and assessment biologists – including the number of times they were mentioned

Position	Most common answers (number of times mentioned after initial mention)
Manager (n=27)	Invasive species (9), Climate change (3), Biotelemetry, eDNA, Barriers, Pathogens, Refined stock assessment tools, Habitat ecology/habitat mapping (2), Understanding stock recruitment relationships (1), Controlling sea lamprey (2), Ecosystems and trophic interactions (5), Managing stock populations, Population dynamics (2), Ecosystem energy transfer/dynamics (1), Lake trout population/mortality/restoration (1), Salmon bioenergetics, Migration, Recruitment (1), Fish passage, Predator-prey dynamics (2),

	Commercial fish harvest and stock assessment, Commercial bycatch, Habitat restoration, Implications of population/demographic change on environment, Nutrient inflow (1), Status of Cisco populations in Lake Superior (1), Asian carp productivity, Coordinated science and monitoring initiatives, Quadra/zebra mussels, Acoustic telemetry, Native species rehabilitation (1), Pre-diversity ecological implications of invasive species, Food web dynamics (1), Microbiome processes, Alternative control techniques, Minimizing risk to non-target species during lampricide treatment
Researcher (n=12)	Productivity change (2), Eutrophication (3), Prey populations, Salmon (1), Native species restoration (2), Prevent invasions, Ecosystem change/dynamics (4), Invasive species (3), Climate change (1), Cisco trends and recovery, Trophic level dynamics (1), Population dynamics, Sea Lamprey dynamics, Decline in fish forage, Better forecasting, Recruitment dynamics, Lake food web dynamics (1), Predator-prey dynamics (1), Energy pathways, Water quality, Habitat dynamics, Fisheries production, Sustainability, Land issues with fisheries
Assessment biologist (n=11)	Species at risk, Prey population status, Native species restoration (1), Invasive species (2), Adaptation to climate change (1), Population dynamics, Species biology, Recruitment, Food web dynamics, Ecological change, Chinook salmon, Water levels, Habitat data, Stock dynamics (1), Energy transfer, Cisco dynamics and ecology, Movement of Brook Trout in Lake Superior, Sea lamprey control management, Restocking/rehabilitating fish communities, Salmon prey abundance and population characteristics in Lake Ontario

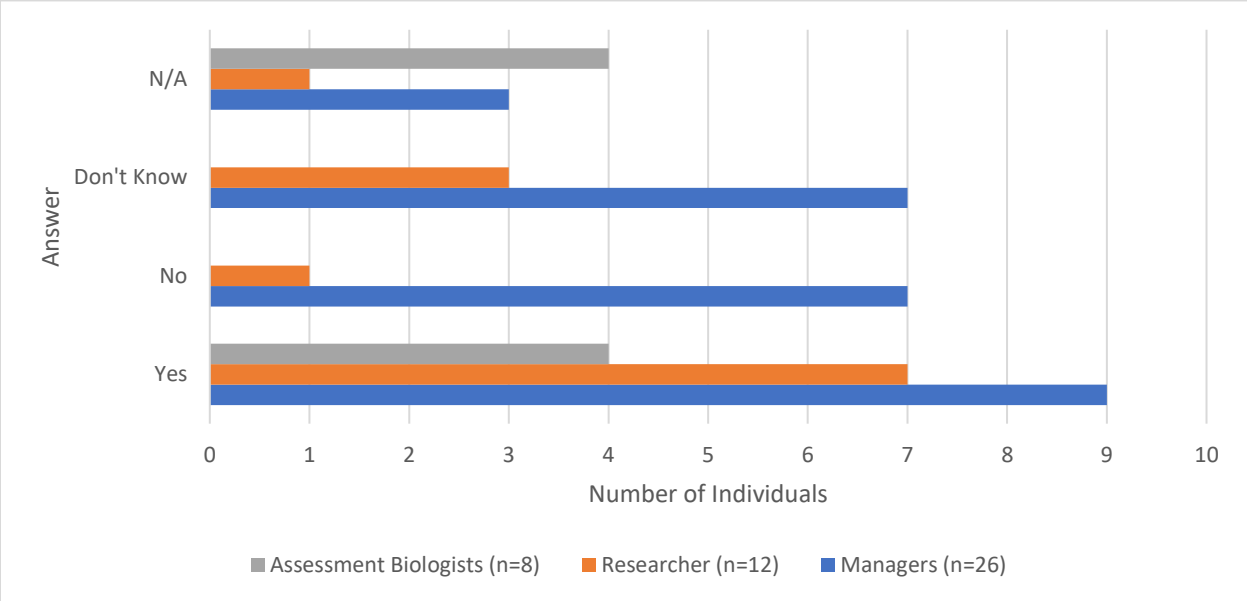

Figure 7. The number of individuals, separated by manager, researcher, and assessment biologist, who gave their opinion on the Science Transfer Program's address of high priority topics

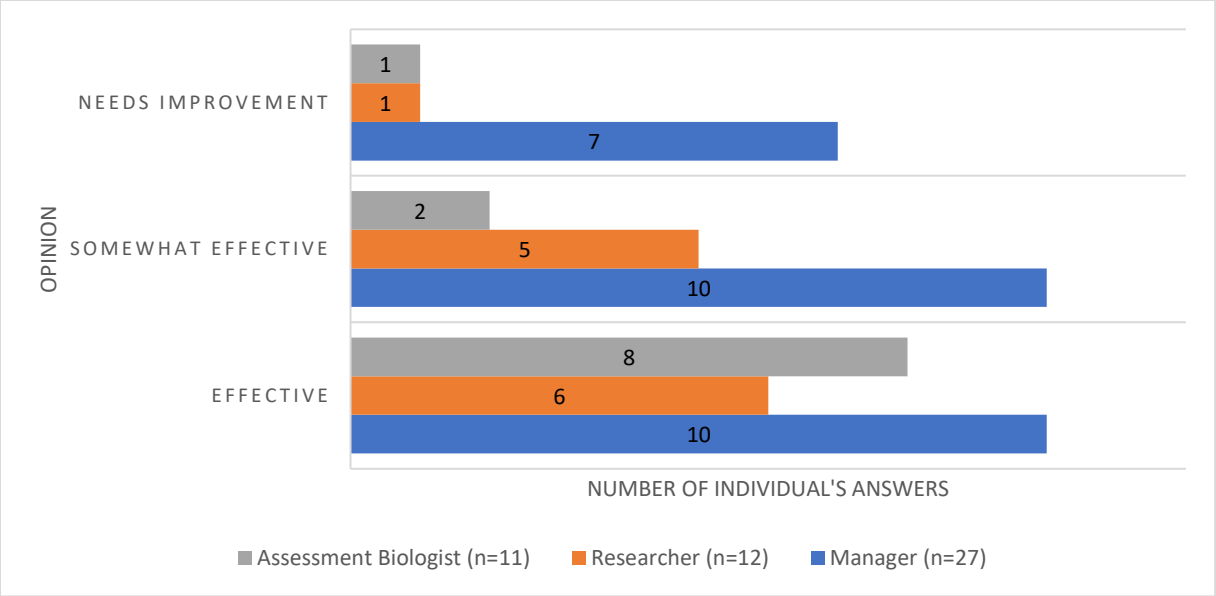

Figure 8. Number of individuals who provided their opinions on the current science transfer in the Great Lakes Basin

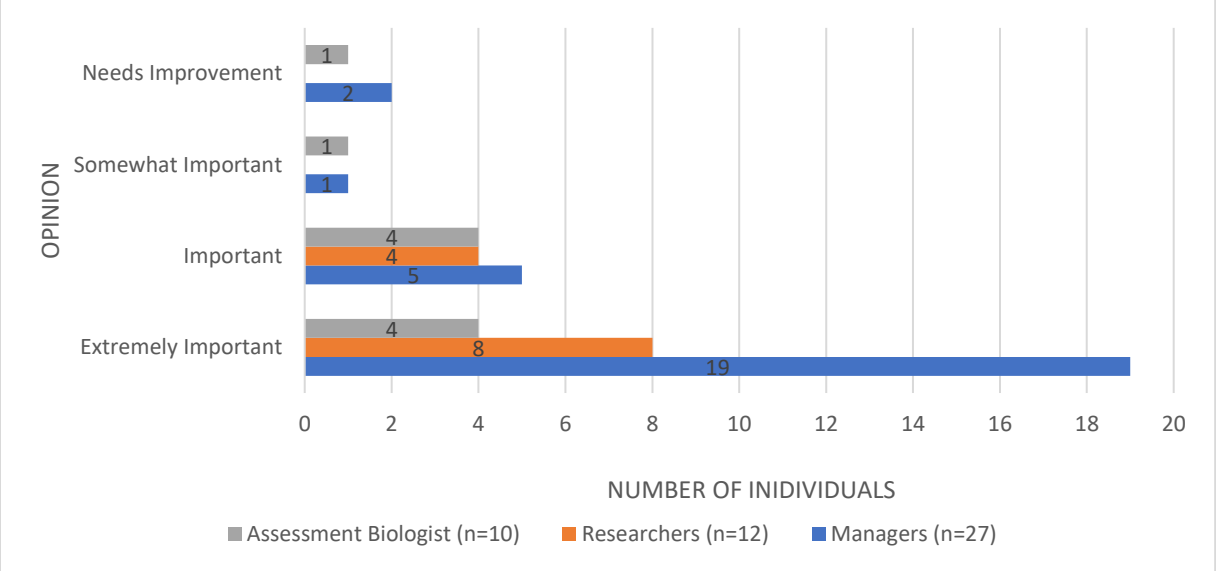

Figure 9. Number of managers, researchers, and assessment biologists and their opinion on the efficacy and importance of annual Lake Committee meetings

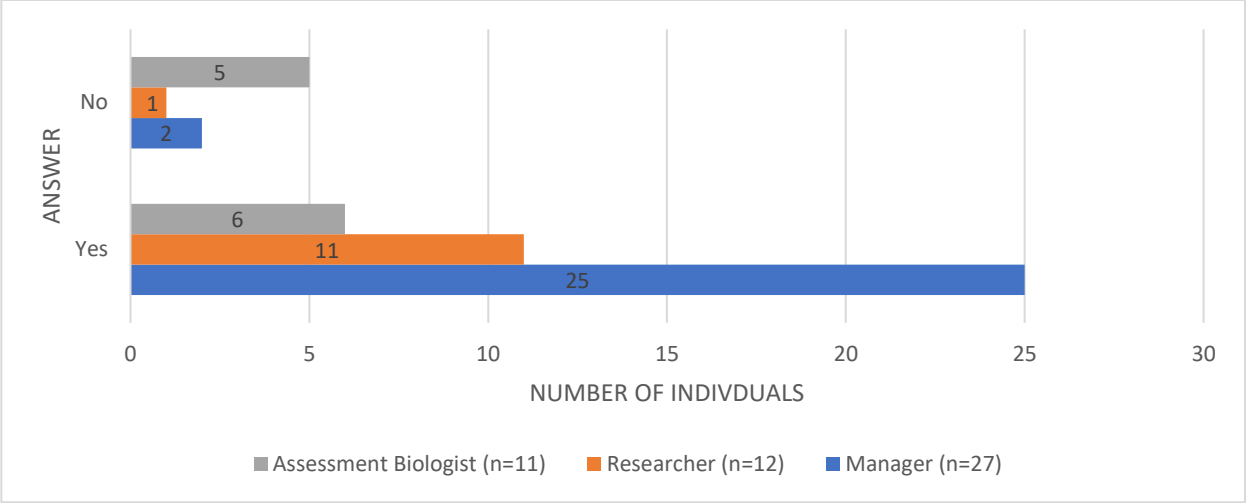

Figure 10a. Number of individuals in manager, research, and assessment biologist positions and whether they are or are not aware of the GLFC initiative to facilitate science

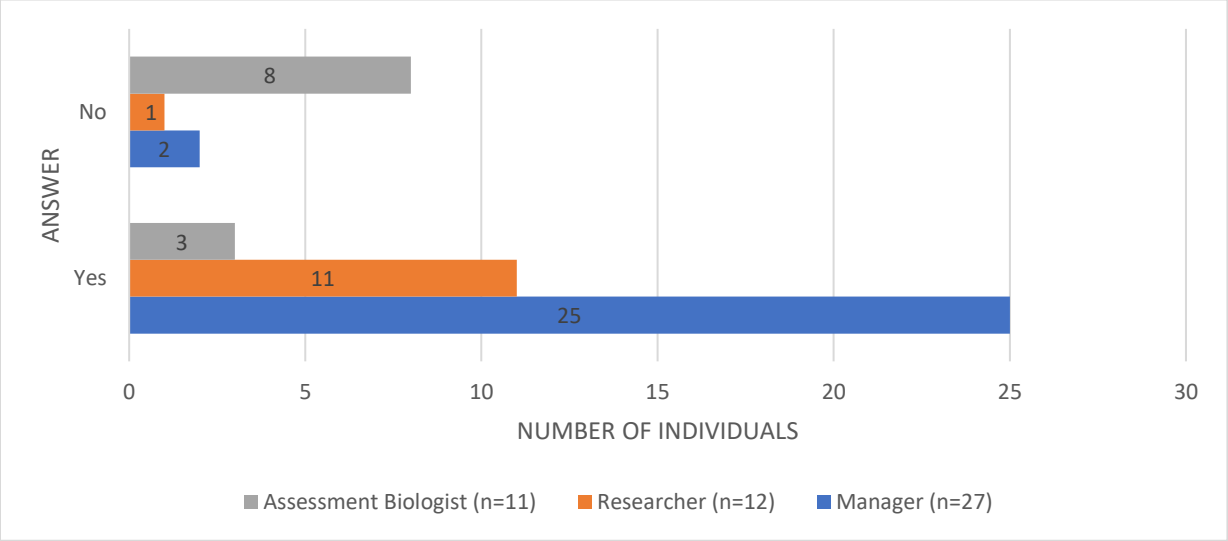

Figure 10b. Number of individuals in manager, research, and assessment biologist positions and whether they are or are not aware of the Science Transfer Program

Effectiveness of science transfer in GL

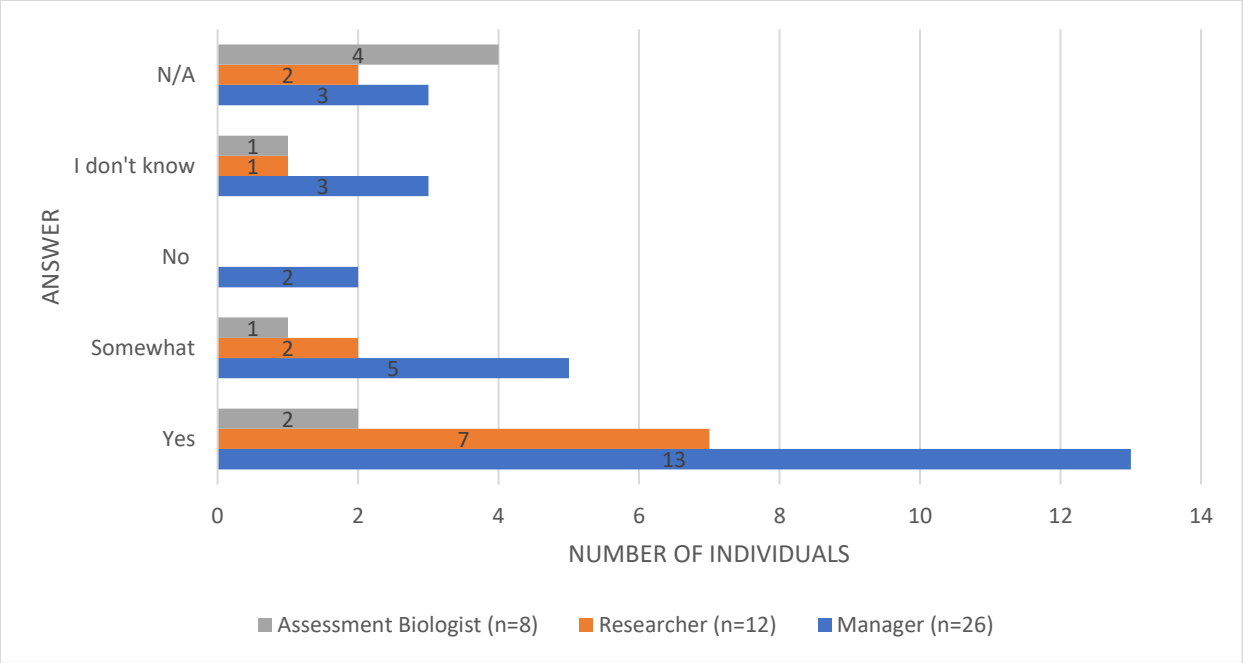

Figure 11. The number of individuals from manager, research, and assessment biology positions and their opinion on how effective the delivery of research findings are by the Science Transfer Program

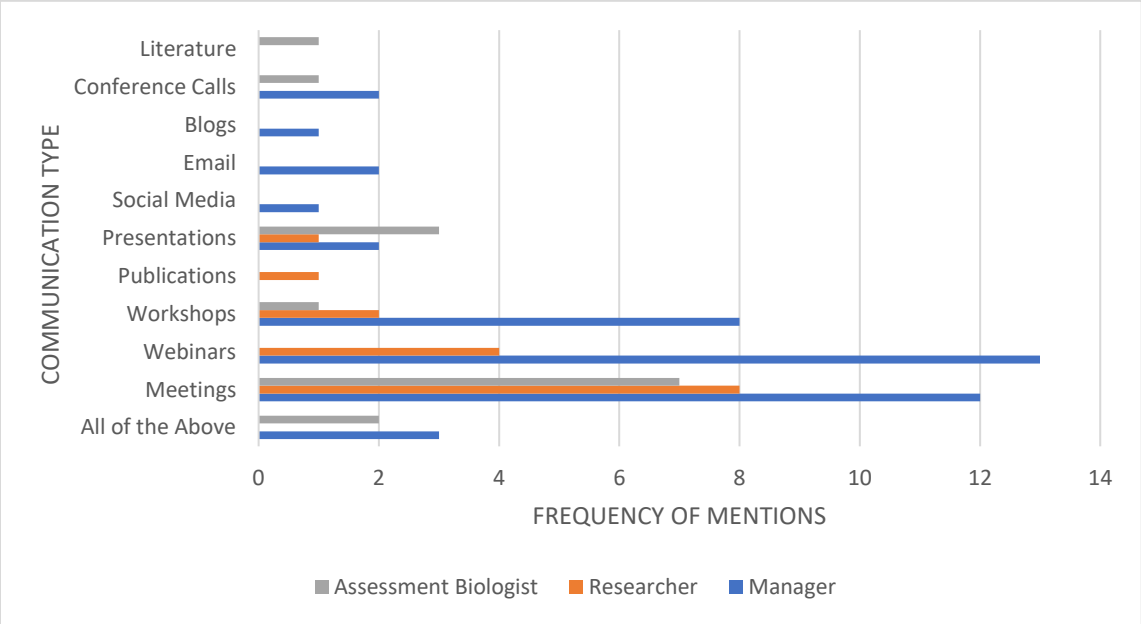

Figure 12. The frequency of mentions given by managers, researchers, and assessment biologists on the most effective forms of communication of research findings to managers/policy makers