

Review

Effective Communication of Coastal Flood Warnings: Challenges and Recommendations

Tianze Pang ^{1,2}, Heather D. Penney ^{3,4} and Xiuquan Wang ^{1,2,*}

- ¹ Canadian Centre for Climate Change and Adaptation, University of Prince Edward Island, St. Peters Bay, PE C0A 2A0, Canada; tpang11616@upei.ca
- ² School of Climate Change and Adaptation, University of Prince Edward Island, Charlottetown, PE C1A 4P3, Canada
- ³ Aquatic Resources Program, St. Francis Xavier University, Antigonish, NS B2G 2W5, Canada; hpenney@stfx.ca
- ⁴ Department of Biology, University of Prince Edward Island, Charlottetown, PE C1A 4P3, Canada
- * Correspondence: xxwang@upei.ca

Abstract: With the increasing risk of coastal flooding facing coastal communities due to climate change, coastal flood warnings (CFWs) are expected to play a critical role in the protection of people and property to ensure communities' sustainable development. However, as destructive coastal flooding hazards have caused considerable damage in recent years, the effectiveness of coastal flooding warnings could be questioned considering their objective of disaster risk reduction. Here, we deliver a review investigation of the current CFWs in the USA and Canada based on their setup and dissemination, and a case study of two representative coastal flooding events. Through this review, we found that collaboration between multi-level administration regarding CFW mechanisms has the potential to strengthen these mechanisms, improving their efficacy. We also found that CFWs presented in the media often lacked consideration of public acceptance and practicability in their reports, which may have affected the performance of these CFWs. Meanwhile, the technological limitations and uncertain public acceptance may also reduce the CFWs' effectiveness in application. Accordingly, the media should further consider the understandability of CFW-related reports. Moreover, emergency information channels should be set in both traditional media and social media for accessible use by residents with different customs. Lastly, starting from the normalized prevention of coastal flood disaster, a consensus of crisis awareness should be built with which the social aspects of the defense against coastal flooding can be established for future environmental sustainability.

Keywords: environmental communication; coastal flood; emergency warning; risk management; disaster reduction



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1. Introduction

Coastal floods have become an emerging environmental risk for coastal communities [1]. Between 1970 and 2010, the global population exposed to once-a-century coastal flooding increased by 95%, to 271 million, while the exposed assets increased from 820 million USD to 13 trillion USD [2]. Coastal flooding is usually caused by a series of environmental drivers, such as climate-related sea-level rises, long-term waves, storm surges, tsunamis and their landfall, extreme precipitation and runoff, vertical geological movement, and artificial environmental transition [3,4]. It has also been reported that the specific geographic conditions may impact the risk of coastal floods, such as the coastal geomorphology and coast types [5,6]. A number of studies have predicted that coastal flooding will continue to be one of the main risks for worldwide coastal environmental security, with increasing intensity (e.g., [7–11]).

As over 40% of the global population [12] and related businesses are located along the coastline, communicating this risk with the public is a necessary and critical component of

environmental risk management, particularly the challenge of coastal flooding. Risk communication is defined as purposeful information and opinion exchange among individuals, groups, or organizations regarding environmental hazards [13], which plays an important role in alerting the public to potential environmental hazards [14], specifically, coastal flood warning (CFW). The core of risk communication regarding these hazards is the need to enable individuals and communities to respond appropriately to a threat, reducing the risk of death, injury, property loss and damage [15]. However, the relevant research records that a significant proportion of flooding warnings were regarded as failures in Europe and Australia when considering with the criterion of reducing flood damage [16]. A large amount of high-damage coastal flooding events consistently occurred in North America over the past decade, such as the floods during Hurricane Sandy in 2012 [17], the winter storm Juno in 2015 [18], winter storm Jonas in 2016 [19,20], winter storm Grayson in 2018 [21], and post-tropical storm Fiona in 2022 [22], which have had severe consequences for the coastal communities. Hence, with the persistent impacts of coastal flooding hazards, the related concerns regarding safety in the coastal regions have never been thoroughly solved.

When facing increasing concern regarding coastal flooding, it is necessary to examine how the CFWs are communicated to the public, in addition to the other responses to coastal flood hazards. This study will assess the effectiveness of current CFWs by investigating the CFW setup and experiences during representative coastal flooding events in the past 5 years in USA and Canada, looking at their pre-hazard warnings and post-hazard assessments (Figure 1). Challenges and corresponding recommendations, along with the relevant influencing factors, will be determined to fill the gaps in the current CFWs. Against the worldwide background of global and regional climate change and growth in the coastal population, it is expected that this research can be used to determine the key points for an effective CFW, to support sustainable coastal environmental management regarding the increasing risk of coastal flooding in the future.

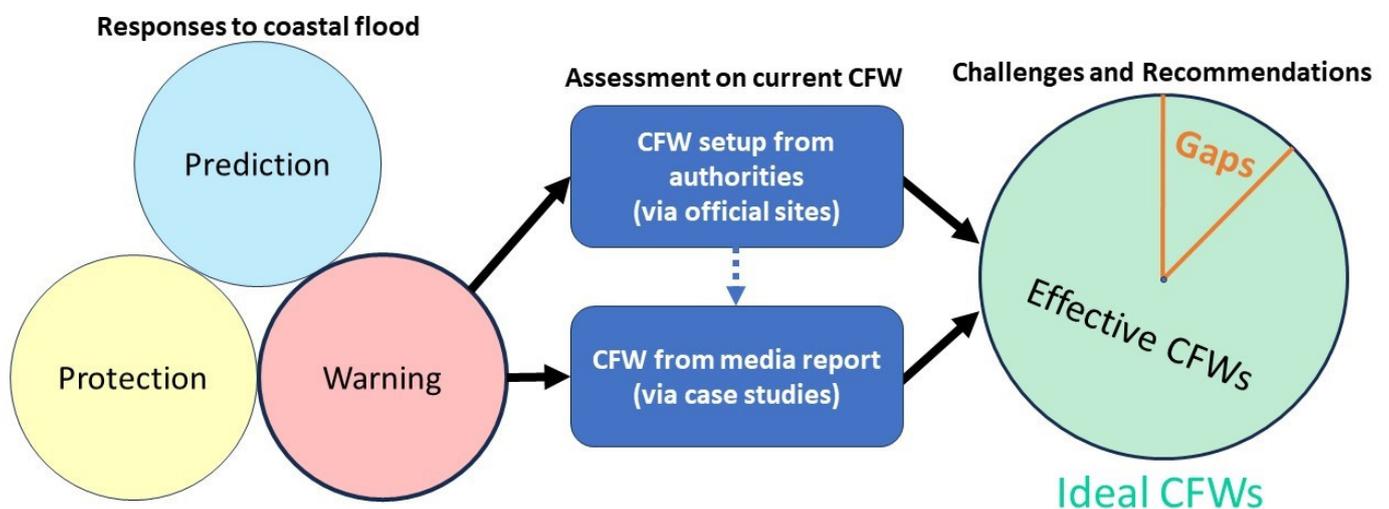


Figure 1. Conceptualization of the research.

2. Communication of CFW

As mentioned above, CFW, as a kind of risk communication, is expected to alert the public to flooding hazards based on information and opinion-sharing among individuals and groups. The release of CFW is related to the forecast of possible extreme weather events in the coastal area according to the intensity of the threat, which considers multiple factors, including meteorological simulation, empirical records, and regional geographic conditions. Following from experience and common sense, in modern societies, relevant authorities and the media usually play the major role in providing disaster warning information for the public. Hence, the authorities and media are regarded as the key players in outputting communication regarding CFWs while the public are the receivers and respond accordingly.

At the same time, the outlet of CFW has been changed with the development of internet technology, which can also potentially impact the effectiveness of communication. Here, we select English-speaking countries with similar social systems and cultural backgrounds, the USA and Canada, for a review of the CFW setup organized by their authorities. Within this scope, we further selected media reports during two typical extreme storm events that caused coastal floods in nearby regions with similar geographic conditions (Figure 2) for a performance assessment of CFWs.

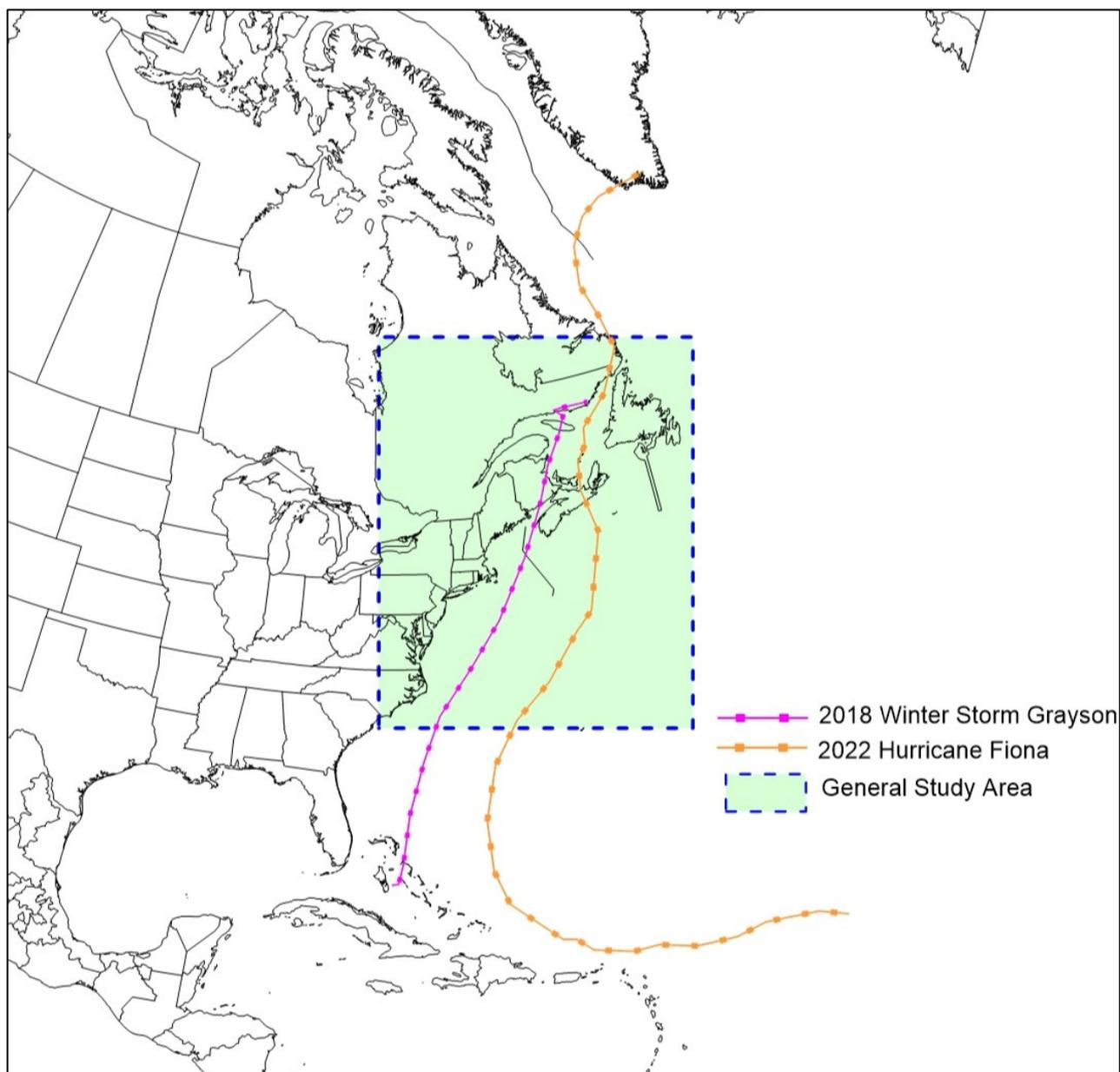


Figure 2. Tracks of selected storm events and related general study area (storm tracks are retrieved from National Hurricane Center (<https://www.nhc.noaa.gov/data/>, accessed on 16 October 2023) of NOAA).

2.1. CFW from Authorities

Regarding the information provided by the authorities, the CFWs of different institutions are varied. The federal authorities of the USA, as well as the National Weather Service and National Oceanic and Atmospheric Administration (NWS and NOAA) [23], define two different levels of coastal flooding hazard forecast, coastal flood WATCH and coastal

flood WARNING, which represent a medium-high or extremely high possibility of flooding events, respectively. Meanwhile, six different threat levels of coastal flood are set based on their destructive power (Table 1). These also provide guidelines for the residents of coastal communities to ensure their rapid response once coastal flooding occurs (Table 1).

As far as we can tell through online research, the national authorities of Canada do not have any specific types of warning or action guidelines for coastal flooding. However, relatedly, Environment and Climate Change Canada ([24] federal government) currently issues alerts for a series of disastrous weather types that could be related to coastal flooding, including hurricanes, tropical storms, rainfall, storm surge, tsunamis, and winter storms. These alerts are currently provided in a qualitative form because no levels of alert have been classified. Among the mentioned types of weather, the warnings regarding storm surges are the most similar to coastal flooding [25], for which a correlated set of guidelines are also provided for residents' actions before and after a storm surge occurs (Table 1). Different from the mechanism of the USA, where the NWS and NOAA provide the alert and guidelines together, the alert of and protection against coastal flooding (storm surges) are in the charge of two different institutions with relevant coordination.

As for the provincial- or state-level CFWs in the USA and Canada, the difference among different states or provinces becomes more variable in terms of their naming, institutional setup, and guideline availability. In this section, we focused on Canada's six coastal provinces. We searched through all the authorities' sites, which can be directly reached, of the provinces that face potential coastal flooding hazards (Table 2). We found that CFWs were not necessarily regarded as an independent item in their weather alerts. For many provinces, flooding, as an entire category of disaster, is considered in their risk warning systems. At the same time, only the provinces of New Brunswick, Nova Scotia, and Quebec have provided straightforward guidelines to the public for reducing risks to their lives and property. In sharp contrast, Prince Edward Island (PEI), one of the provinces facing the highest risk of coastal flooding [26,27], has the least direct CFW information on its official site, although it is noteworthy that a free course named Protecting PEI Homes from Flooding and Erosion is provided to the public through the cooperation between the provincial government and academia.

Table 1. National level CFW of USA and Canada.

Country	Institution	Alert Type	Warning Level
United States of America	NWS and NOAA	Coastal Flood	<ul style="list-style-type: none"> Two levels of warning (Coastal Flood WATCH and Coastal Flood WARNING) Six levels of threat (Non-Threatening, Very Low, Low, Moderate, High, Extreme)
USA—coast Flooding Safety rules [23]			<ul style="list-style-type: none"> Be especially cautious at night when it is harder to recognize the dangers of coastal floods. Don't stay near the coast when water begins rising. Take immediate action to protect property in the event of coastal flooding, including securing all loose objects, boarding up windows close to the ground, and knowing your evacuation routes. Be prepared to leave immediately if coastal flooding becomes imminent. If you should become stranded, stay indoors and move to the highest floor. Bring water, food, a flashlight and a portable radio. It is extremely dangerous to fish or observe the waves from exposed coastal structures during heavy surf conditions, as large waves can suddenly sweep across previously dry areas.

Table 1. *Cont.*

Country	Institution	Alert Type	Warning Level
Canada	<ul style="list-style-type: none"> Environment and Climate Change Canada (issuing alert) Public Safety Canada (providing guidelines) 	Storm Surge	No Classification
Canada—Coastal flooding (storm surge) Guidelines [25]	<p>Preparing for a storm surge</p> <ul style="list-style-type: none"> Check your house and land for any potential dangers related to flooding. Identify any vulnerability and repair it. Sandbags are a valuable tool to prevent water from entering your home. This approach requires specific instructions from your local emergency officials. Learn how to turn off the gas and electricity in your house. You may be instructed by local authorities to shut these off. If you live in an area that is subject to flooding, do not store your important documents in the basement. Keep them at a higher level, protected from flood damage. Ensure that your family has an emergency kit and plan. Ensure your emergency kit is portable, in a backpack or suitcase with wheels. Your local chapter of St. John Ambulance can teach you first aid and CPR. Your local Red Cross can teach you survival techniques in the water through their swimming and boating courses. <p>If a storm surge is forecast</p> <ul style="list-style-type: none"> Check supplies including medications, radio, flashlight and batteries. You may have to evacuate. Keep your emergency kit close at hand. Make sure the basement windows are closed. Fuel your car. If evacuation becomes necessary, it will be hard to stop for gas. <p>During a storm surge</p> <ul style="list-style-type: none"> Stay inside where you are protected from the water. It’s best to be on the downwind side of the house, away from windows. Monitor the storm’s progress and listen for warnings or instructions from local officials. Before driving anywhere, listen carefully to rescue officials who will be coordinating evacuation plans. Do not drive through flood waters. Be aware of risks such as hypothermia from cold water or drowning from running water. 		

Table 2. Provincial CFWs in Canada.

Province	British Columbia	New Brunswick	Newfoundland and Labrador	Nova Scotia	Prince Edward Island	Quebec
Alerting item	General Flood	General Flood	General Flood	Coastal Flood	Coastal Flood	Storm Surge and Shoreline Flooding
Institution (and reference)	River Forecast Centre [28]	Emergency Measures Organization [29]	Department of Environment and Climate Change [30]	Department of Environment and Climate Change [31]	Department of Environment, Energy and Climate Action [32]	Government of Quebec [33]
Official Monitoring platform Guidelines provided	Yes	Yes	Yes	No	No	Yes
	No	Yes	No	Yes	No	Yes

The variation in state-level CFWs in the USA is also significant; however, the NWS and NOAA [34] Safety Program has a platform providing flooding information (both alert and guidelines) for every coastal state in the country, which provides a basic guarantee of

state-level CFWs from the authorities. Compared to the NWS and NOAA, Environmental and Climate Change Canada (ECCC) also provides weather warning information for each province; however, the information is limited to alerts, statements, or summaries of relevant hazardous weather. From the authority sites of each state in the USA, the forms of CFW show similar differences to those of Canadian provinces. For example, when comparing the states of New England, Maine provides introduction and criteria regarding coastal flooding hazards from its Emergency Management Agency [35]; New Hampshire only contains a summary of the coastal flooding investigation from its Department of Environmental Service [36]; the Massachusetts Emergency Management Agency [37] provides comprehensive guidelines for residents to reduce the risk to their life and property during flooding; Connecticut updates the newest weather alerts on the site of its Division of Emergency Management and Homeland Security [38]; the government of Rhode Island does not have any sites for CFW or relevant hazard information except a page regarding Floodplain Management, while the city of Providence [39] provides a basic introduction and notice for residents. When comparing the CFW setups of the New England states, those of Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut have high similarities to those of Nova Scotia, Newfoundland, Quebec, Prince Edward Island and British Columbia (Table 2), respectively. However, most of the New England states added a reference to the NWS and NOAA to their official webpage for residents seeking detailed information, while a similar connection was not found at the authorities' sites in Canadian provinces.

Through the review of CFWs from federal, provincial, or state authorities in the USA and Canada, we found that the public can receive basic alerts or action guidelines from at least one site of authority. However, the recent research findings (e.g., [40–42]) still suggest that communication between the authorities and the public usually necessarily requires information to be transferred through the media to increase an alert's impact and to reach a wider audience. Hence, the performance of media in CFWs also needs to be investigated.

2.2. CFWs from the Media

Different from the normalized information updates from authorities, the CFWs received from the media are usually based on specific coastal flooding events. Therefore, we studied the warnings and disaster assessments of two representative coastal flooding events: the coastal flood in Northeast USA during the winter storm Grayson in 2018 and the coastal flood in Maritime Canada during Hurricane Fiona in 2022 (Figure 2). Relevant CFW information for these coastal flooding events from the media was collected from the News category of the Google search engine.

2.2.1. Case Study I: Winter Storm Grayson

The Winter Storm Grayson, also known as the January 2018 North America blizzard, caused widespread and severe destruction of the east coast of the USA and Canada. In the Northeast USA, over 20 deaths and over 1.1 billion USD in property damage was reported [43]. Many coastal communities experienced unprecedented coastal flooding events during the storm [44]. Using the keyword search of "coastal flooding, winter storm Grayson", a total of 55 results were found, of which only 10 contained available CFW information before the storm center passed this region (i.e., 4 January 2018). Regarding the CFW content, all 10 of these media reports contain a warning of potential of coastal flooding hazards. Of those 10, 4 mentioned the potential consequences that could be caused by coastal flooding, and only 3 of the 10 mentioned potential actions that residents should take to mitigate the impact of the coastal flooding disaster (Table S1). Focusing on the specific rhetoric or content of the reports, the media reports either used the warning of "minor flooding" according to NWS's bulletin or used the plain expression of the "possibility of coastal flooding" based on the same information source. As for the content of this consequence warning, four related reports mentioned the possibility of a power outage or inundation. Regarding the action guidance, the content in the media reports only referred to the relevant warning from the authority press conference, which basically warned residents

not to go outdoors during the extreme weather event. When the CFW and guidelines are compared to the real experience of coastal flooding, many residents that were impacted by coastal flooding in their communities were actually stuck in their houses before they realized the severity of the flood [45]. Hence, the most correct guidance for these residents should have been “evacuation” or at least “to prepare emergency supplies for at least the estimated number of days”, instead of only “not to go outdoors”. It is also noteworthy that most of the reports containing CFW information were released no earlier than 4 January, 2018, while initial coastal flooding had already occurred on 3 January, 2018, at several coastal sites in the mid-Atlantic USA. This also confirms the opinion post-storm that the extent of the coastal flooding was underestimated at the beginning of the forecasting [46], meaning that there was not enough time for residents to consider and prepare for the impact of coastal flooding.

A series of released media interviews with local communities regarding their experience in the coastal floods also proved that a lack of experience and a lack of accurate predictions could weaken the preparedness for potential hazards. It has been reported that residents in the town of Scituate first prepared by stocking supplies, together with crews working on a seawall, while a short while later they were asked to voluntarily evacuate [43]. A similar experience also happened to people in Gloucester, whose cars were flooded because they were asked to park them in an emergency parking lot. The Chief Administrator of Gloucester attributed this to their lack of experience with such an extreme flood, which was similar to the opinion of the Mayor of Boston that no similar scale of flooding had ever occurred in the region [43]. A coastal engineering group pointed out that coastal protections against potential floods might lead to totally different results when comparing the Brewster and Provincetown areas [47]. In addition to engineering protection, a more comprehensive adaptation management action plan could play an important role in the future if people learned from storm Grayson and attempted to establish such a plan [46].

2.2.2. Case Study II: Hurricane Fiona

Hurricane Fiona, also as known as post-tropical storm Fiona, passed the east shore of North America in late September, 2022. This was regarded as the severest storm on record in Atlantic Canada. It was initially estimated that, in Atlantic Canada, the total damage was 4 billion CAD and the storm resulted in 25 people dying [48]. It had already caused considerable damage in Puerto Rico, Bermuda, and some coastal sites of the USA.

Through the keyword search of “coastal flooding Hurricane Fiona”, 243 results were found. For the CFW reports before Hurricane Fiona landed in Atlantic Canada (i.e., 24 September 2022), only 17 of them contained relevant CFW information (Table S2), already shown an increase in amount compared to the information available for storm Grayson. Among them, 12 reports contained a description of the potential consequences of coastal flooding and other associated disasters, and 10 of them provided guidance for residents’ emergency actions. Significantly different from the reports for Grayson, five reports of the CFW for Fiona contained comprehensive and detailed guidelines regarding coastal flooding, including lists of emergency supplies, lists of actions to take at different potential stages, and evacuation as a last resort. The other action guidance also provided simple but marked instructions, including avoiding going outdoors, and following the instructions of the local emergency agency. There were even specific reports focusing on guidelines and preparedness for the coastal flooding hazards for the residents that were published before Hurricane Fiona’s landfall [49,50]. When compared to the CFWs for the 2018 storm Grayson, people paid more attention to the potential coastal flooding hazards before Fiona landed, which could probably be regarded as an increase in awareness of the need for disaster preparedness based on the increased experience of extreme weather.

However, the CFW still did not prevent all the damage caused by coastal flooding during Fiona, even though there was a relative improvement in the media reports. From a third-party review of post-Fiona actions in PEI, only 20% of the surveyed public felt confident in the province’s ability to effectively respond to and recover from the post-

tropical storm [51]. This could be due to the experience of long power outages, long line-ups and shortages of fuel, and the difficulty many residents had in accessing the provincial support funds distributed by the Red Cross. Moreover, it has been emphasized that communication between government departments, aid agencies, and the public was a challenge during Fiona and needs to be improved. Similar to PEI, different stakeholders in the province of Nova Scotia also reported a series of challenges in coastal protections and effective communication following the experience of Hurricane Fiona [52]. Based on the results of a post-flood review of the two studied events, it is still important to discuss the current potential for CFW improvement presented in the above reviews.

2.3. CFW Dissemination

In addition to the review of the two main sources of CFW information, the outlet of CFW dissemination is also a factor impacting its effectiveness. With the development of internet technologies, social media (e.g., Facebook, X (formerly Twitter), Instagram, and discussion forums) has started to play an important role in sharing information and risk communications, together with traditional channels (e.g., newspapers, magazines, TV, radio, telephone, websites, and in-person communications). However, relevant research has reported that the diversification of information outlets did not directly improve the efficiency or effectiveness of CFWs [53]. This makes residents' preference regarding sources of information more divided, which is related to multiple factors, such as age and flood experience. Specifically, the dissemination of CFWs using social media is more popular among younger generations, while older generations still prefer to receive their information from traditional sources and may not desire to receive information from newer media sources [53]. Related to the experience with both the 2018 storm Grayson [54] and 2022 hurricane Fiona [55], social media has been proven to play a significant role in CFW dissemination. Going from CFW to a wider range of risk communication, the wildfire evacuees in the Northwest Territories of Canada reported that the ban on sharing news via Meta (i.e., Facebook and Instagram) by the Canadian press, which blocked most media reports from the Canadian press on its platforms from June 2023, is dangerous as regards warning information dissemination before and during evacuation [56]. This also laterally proves that social media has become an important channel for risk warning information for a significant number of people. Hence, the disunity of CFWs shared through different dissemination channels (i.e., social media and traditional media) should also be noted in the development of CFWs, in addition to the disunity among their sources (i.e., the authorities and media).

3. Challenges

Through comparing the CFWs for two representative coastal floods (the 2018 winter storm Grayson and 2022 hurricane Fiona), we found that there were some improvements but there are still several noticeable gaps in the CFWs based on the goal of effectively reducing risks to life and property. Looking at the CFW setup of relevant authorities in USA and Canada, a discussion of their effectiveness should focus on multiple aspects, including the media, public acceptance, and scientific support.

3.1. Complexity in Compound Flooding Prediction

Coastal flooding, as a typical compound flooding with multiple drivers, such as tide, wave run-up, streamflow, and precipitation, is still facing the challenge of accurate forecasting by the scientific community [57–60]. Hence, the source of the CFWs, as well as the forecast of compound flooding, may contain some uncertainty. In other words, they often overestimate or underestimate what can happen during a coastal flooding event. As a typical example, for the CFWs given during the 2018 Grayson event, the warning levels shifted from “minor” to “moderate”, and finally to “major” during the occurrence of the coastal flooding disaster [46]. The technology used in compound flooding forecasts has to be continuously improved to increase the accuracy of these predictions. At the

same time, due to the complexity of the local geographic conditions, the meteorological intensity of extreme weather events, and the level of local communities' development, the assessment on CFWs remains at a non-systematic stage. However, to ensure risk reduction at any moment, bottom-line thinking should be constantly utilized when establishing CFWs, which means that warnings and preparedness information should be delivered to the public as much as possible, even if the prediction could be overestimated.

3.2. Simplifications from Authority to Media

As mentioned in Section 2.1, regardless of the administration level, there are guidelines for each American and Canadian region, which should provide enough information for action. However, during the 2018 Grayson coastal flood, few of the media reports delivered comprehensive guidelines to the public. In the CFWs of the 2022 Fiona coastal flooding, during which more relevant information was presented, it is still hard to suggest that comprehensive guidelines were widely provided to the public. As the media usually play a more important role in spreading the information provided by the authorities to the public, this simplification of the warning content has the potential to reduce the effectiveness of CFWs presented by the authorities. A common trend was seen in the selected two events where the media prefer to directly cite recently released notices in their relevant reports, such as the information from the NWS or local emergency department, while the related supporting content is usually not included in the report. In this case, the supporting information, which is normally provided by authorities and is usually more effective in protecting residents' safety, has more difficulty reaching the public to guide their actions. To solve the problems potentially caused by simplification, the authorities should guarantee the availability of emergency action guidance in their CFW releases. Moreover, the media should be aware of the social responsibility of providing action guidelines at the same time as newsworthy reports focusing on the disaster.

3.3. Lack of Consideration on Understandability

In the CFWs regarding the 2018 storm Grayson, the terminology of "minor flooding" was widely used in the media reports, which was originally used in the NWS bulletin. It is understandable that institutes like NOAA and ECCC must present their bulletins in a professional way, but it could be more helpful if every release contained some basic explanation of the relevant terminology. In media reports, understandability may be considered a lesser responsibility if the terminology in the CFW news bulletins is presented to the public. Without professional knowledge, the word "minor flooding" could be understood to totally different extents by different individuals. Also, the terminology of each warning level may not accurately reflect the experience of coastal flooding. Specifically, "minor flooding" could be based on the possibility of flooding, the flooding area, and the period for which flooding lasts, but for the residents who go through the flooding disaster, the damage they experience should not be simply described as "minor". Fortunately, in the rhetoric of CFWs for the 2022 hurricane Fiona, a considerable improvement was shown in comparison to that used for the 2018 Grayson storm. In several media reports, the situation of communities suffering from coastal flooding was explained using straightforward expressions, such as "shoreline infrastructure, roads, causeways, dikes, retaining walls and boardwalks are all at a significant risk from wave action" [49]. Therefore, instead of directly citing the terminology from the authorities, some information presenting the warning or forecasting in plain language is expected to be provided to the public, so that effective communications can be made, surpassing the professional barrier of rhetoric.

3.4. Uncertainty Regarding CFW Acceptance

Together with the uncertainty regarding the scientific understanding of coastal flooding forecasts, the acceptance of the public is another challenging aspect regarding the effectiveness of CFWs. Even assuming that all the CFWs are well-made by the authorities and media, the public may still behave differently regarding how closely they follow in-

structions. Following the direction of information dissemination, it has been indicated that the presentation of scientific evidence alone would weakly influence public attitudes and behaviors in risk communications [61]. Accordingly, efforts to increase acceptance should focus on providing and promoting awareness of the safety and benefits. The relevant research has reported that communication regarding how to protect against floods, together with information about flood risk, is much more effective than the traditional strategy of communicating only about flood risk [62]. Hence, building up a common sense of crisis awareness towards coastal flooding in geographically risky coastal communities may become the objective in CFW improvements. The more frequent extreme coastal flooding events have increased the risk for coastal communities, and provided the public with more experience in establishing a consensus, which can be summarized in the statistics of CFWs from the 2018 storm Grayson to the 2022 hurricane Fiona. More administrative means with a higher efficiency and more systematic adaptation management action plan are expected to be designed and used to supporting collaboration with the public [46]. In addition, people's preference regarding the information channels of CFW dissemination impacts their acceptance. It has been indicated that the social networks of individuals can have a significant effect on whether they take protective action or not [62], which suggests that flood risk communication should focus on the natural amplifying effect of social networks (i.e., social media, in most situations at present). Especially when facing coastal floods, which can have swift changes in intensity based on the original forecast, rapid responses and frequent updates should be delivered to people via multiple information channels. Hence, the hysteresis of traditional media and information blockages on social media (e.g., Meta's ban of Canadian press) can also impact the effective acceptance of CFWs among different groups of people.

4. Recommendations

We looked to the CFWs provided by the authorities in USA and Canada, the relevant media reports for two representative coastal flooding events, and the dissemination of CFWs from their source to the public. Although the CFWs of media focusing on the 2018 winter storm Grayson and 2022 Hurricane Fiona showed some progress, current CFWs still face the challenges regarding uncertainty in coastal flooding forecasts from a scientific perspective, which remains an area in which progress should be made in the relevant research fields. However, regarding the delivery of CFWs from the authorities and media to the public, there are also a series of flaws that can be improved, including deficiencies in key supporting information, and a lack of consideration of the need for understandable rhetoric. To solve these different challenges that we found regarding the communication of CFWs, correlated solutions are recommended.

4.1. Unification and Collaboration among Authorities

Through this review, we found that the CFWs presented by the authorities in the USA and Canada provided basic guidelines at the federal level; however, there was a lot of variability between state- or provincial-level institutes, which may leave confusion or gaps in coastal residents' ability to obtain useful information. Accordingly, in addition to the federal-level support for CFWs, some of the state- and provincial-level authorities should improve their CFW mechanisms, including listing guidelines for emergency preparedness and updating the flooding monitoring system. The coastal flooding platform of the NWS and NOAA, which contains divisions for each coastal state in USA, provides an ideal example of CFW unification for the different coastal regions inside a country. Establishing and popularizing a similar standardized platform may require more administrative efforts and collaboration among multi-level governments; however, this could mostly avoid the disunity and conflict that existed in the previous CFWs.

4.2. Consideration of Acceptability in Media Reports

As the widely regarded main CFW source, the media should try to deal with the challenges of the simplification of key information and non-understandable rhetoric. They should provide the necessary supporting information for the public, up-to-date disaster news, and a comprehensive introduction of the consequences of potential hazards and correlated action guidelines. The media should also use plain or understandable language to interpret terminology or professional concepts for the public. In order to facilitate effective CFWs via the media, relevant criteria should be created to guide and to supervise the press coverage of extreme weather events.

4.3. Emergency Information Channels in CFW Dissemination

For various channels of CFW dissemination, whether traditional or new, the delivery of key messages should become the objective in their operations. Coastal floods, as an increasingly frequent natural hazard that is still relatively inaccurately forecasted, require timely updates through multiple information channels before and during any events. For the groups, such as the elderly, who prefer to receive relevant information through traditional channels (e.g., the radio, printed newspaper), extra preparedness should be made to close the gap of information delays, such as setting duty officers for coastal community networks to ensure that notifications and necessary help are provided. For the dissemination of CFWs via social media, content restrictions (e.g., Meta's Canadian news ban) should stop or at least pause during these critical times to make way for emergency information. This requires cooperation between related governments and internet corporations to set aside arguments and ensure that the safety of residents' life and property when facing extreme coastal flooding events take priority.

4.4. Establishment of Crisis Awareness

The uncertainty of coastal flooding forecasts and public acceptance, as the main external factors of CFWs, still challenge the effectiveness of communication. Correspondingly, bottom-line thinking strategies should be utilized to establish a social consensus and defensive line against coastal flooding hazards. The experience in the reviewed coastal flooding events shows that quite a few of the affected cases could have been impacted by the lack of awareness regarding potential severe floods. For coastal floods, as a typical kind of compound flood that is difficult to accurately forecast, the establishment of crisis awareness in coastal communities could be a start and is one of the most important steps in the protection of people's life, property, and infrastructure security. In other words, all the other preparedness, in terms of institution, mechanism, infrastructure, and action, can be facilitated more smoothly with a stronger consensus regarding coastal flooding crisis awareness. The public, especially those who are more likely to go through coastal flooding disasters, must participate or be enrolled in the overall process of CFW and preparedness. Specifically, for residents living in areas with a higher possibility of coastal floods, the popularization of and education regarding basic hazard knowledge and survival guidelines should be provided by the municipality or cooperated organizations. Regular emergency exercises in easily affected communities may also be a practical option.

4.5. Application with Regional/Local Situations

Based on the review of events in the USA and Canada, site-specific factors may lead variations in the impact coastal floods. These factors may include geographic conditions, local protective infrastructure, population or property densities, the experience of residents, etc. Hence, the communication of CFWs should also be applied with consideration of these site-specific conditions. From a global perspective, several more factors should also be included, such as the mobilization force of the society, the scientific and technical levels of the predictions, disaster prevention costs, etc. It is recommended that CFWs are delivered through all possible channels (e.g., official notifications, prediction platforms, and multi-media reports) and emphasized on the most-used local channels for the public. If there

is an extremely high possibility of coastal floods, or limitations regarding the technology and the cost (e.g., in relatively less-developed regions), the bottom-line principle should be weighed in case of underestimation, which means that the treatment or evacuation strategies may have a higher priority compared to other locations.

5. Conclusions

This research aims to assess the effectiveness of current CFW communications regarding the roles of the authorities and the media. Previous experience of CFWs' setup and dissemination in the USA and Canada, obtained through the review and analysis, suggests several aspects that could potentially be improved. Multi-level authorities are recommended to create a tighter collaborative mechanism for future CFW releases to avoid the different information resources being out of step. The media, in reports related to coastal floods, should set the objective of helping the public to accept useful information regarding the emergency, in addition to always ensuring the newsworthiness of the reported news. Social media, together with traditional media, should create emergency channels for future CFW information, regarding their significant impact on societies at present.

Furthermore, CFWs, as a kind of risk communication for environmental hazards, struggle to achieve the goal of disaster reduction due to limitations regarding the relevant scientific understanding, and the natural and social conditions of different coastal communities. In the worst case, CFWs may only provide a last resort for residents, as well as evacuation, without being able to protect the infrastructure and properties near the sea. Therefore, as an important part of disaster reduction, CFWs also need to collaborate with other related progress, including flooding forecasts, emergency administration, social education, disaster prevention design, and urban–rural planning, to finally meet the needs of coastal flooding prevention in the future.

In summary, current gaps in the studied content regarding the creation of an ideal CFW can be concluded as follows:

1. Authorities at different levels lack efficient coordination for source CFWs; a united mechanism should be established for coastal floods and other risk communication.
2. The media usually focus more on news value, but cannot always provide effective guidance to the public. A set of guidelines is recommended for future media reports regarding CFWs: (a) all the CFW reports should include action guidance for emergencies during coastal floods; (b) plain language needs to be applied if the source information contains professional terminology; (c) multiple channels need to be utilized for CFW releases, including as many as channels possible to ensure the widest acceptance.
3. An unbalance in geographic and socio-economic conditions may cause variations in coastal flooding's impact on specific locations, while a lack of relevant experience makes it easy to underestimate this impact; the bottom-line principle is necessary for the estimation of hazards in CFW communications.

Lastly, this research may also have a few limitations in its scope and investigated content. The area selected for the CFW setup was limited to the USA and Canada, which may not comprehensively represent all the typical situations of coastal floods globally. Hence, a consideration of multiple factors related to locations is included in the recommendations based on the comparison of the selected regions and the comparison between North America and other coastal regions around the world. Additionally, our investigated content from the internet may also have different biases due to the subjective feelings of the surveyed population. It is common for people to attribute poor disaster responses to the authorities, without considering media reports, and it is possible for them to exaggerate or underrate the disaster. With the comprehensive consideration of the multiple summarized factors, the sustainability of coastal communities in the face of flooding hazards is expected to improve.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su152416693/s1>, Table S1. CFW media reports of 2018 winter storm Grayson; Table S2. CFW media reports of 2022 Hurricane Fiona.

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