



**SHERLOCK**

# **SHERLOCK SECURITY REVIEW FOR**



**Prepared for:**

**Carapace**

**Prepared by:**

**Sherlock**

**Lead Security Expert:**

**clems4ever**

**Dates Audited:**

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**Prepared on:**

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# Introduction

Building DeFi's newest primitive - connecting buyers & sellers of credit default risk in crypto loans.

## Scope

All contracts in `contracts` folder, excluding `test` folder.

`./:`

- `UUPSUpgradeableBase.sol`

`./adapters:`

- `GoldfinchAdapter.sol` : upgradeable using UUPS pattern

`./core:`

- `ContractFactory.sol` : upgradeable using UUPS pattern
- `DefaultStateManager.sol` : upgradeable using UUPS pattern
- `PremiumCalculator.sol` : upgradeable using UUPS pattern
- `ProtectionPoolCycleManager.sol` : upgradeable using UUPS pattern

`./core/pool:`

- **`ProtectionPool.sol` : This is core contract of the protocol and upgradeable using UUPS pattern**
- `ReferenceLendingPools.sol` : upgradeable using UUPS pattern
- **`SToken.sol` : ERC-20 compliant implementation of the interest bearing token for the Carapace protocol**

`./external/goldfinch:`

- `ConfigOptions.sol`
- `ICreditLine.sol`
- `IGoldfinchConfig.sol`
- `IPoolTokens.sol`
- `ISeniorPool.sol`
- `ISeniorPoolStrategy.sol`
- `ITranchPool.sol`
- `IV2CreditLine.sol`

`./external/openzeppelin/ERC1967:`



- ERC1967Proxy.sol
- Proxy.sol

./interfaces:

- IDefaultStateManager.sol
- ILendingProtocolAdapter.sol
- ILendingProtocolAdapterFactory.sol
- IPremiumCalculator.sol
- IProtectionPool.sol
- IProtectionPoolCycleManager.sol
- IReferenceLendingPools.sol

./libraries:

- AccruedPremiumCalculator.sol
- Constants.sol
- ProtectionPoolHelper.sol
- RiskFactorCalculator.sol

## Findings

Each issue has an assigned severity:

- Medium issues are security vulnerabilities that may not be directly exploitable or may require certain conditions in order to be exploited. All major issues should be addressed.
- High issues are directly exploitable security vulnerabilities that need to be fixed.

## Issues found

Medium	High
9	12



## Issues not fixed or acknowledged

Medium	High
0	0

## Security experts who found valid issues

clems4ever  
OKage  
bin2chen  
jkoppel  
rvierdiiev  
libratus  
Koolex  
Jeiwan  
0x52  
monrel  
chaduke  
immeas  
Allarious  
mahdikarimi

ck  
charlesjhongc  
minhtrng  
XKET  
KingNFT  
MalfurionWhitehat  
Tricko  
\_\_141345\_\_  
dec3ntraliz3d  
VAD37  
Web3SecurityDAO  
ctf\_sec  
unforgiven  
modern\_Alchemist\_00

Kumpa  
Bauer  
Ruhum  
c7e7eff  
ast3ros  
mert\_eren  
jprod15  
peanuts  
yixxas  
SPYBOY  
HonorLt  
carrot  
csanuragjain



## Issue H-1: The renewal grace period gives users insurance for no premium

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/308>

### Found by

monrel, 0x52, jkoppel, libratus

### Summary

When a protection position is renewed, the contract checks that the expired timestamp is within the grace period of the current timestamp. The issue is that when it is renewed, it starts insurance at block.timestamp rather than the expiration of the previous protection. The result is that the grace period is effectively free insurance for the user.

### Vulnerability Detail

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/libraries/ProtectionPoolHelper.sol#L390-L397>

When checking if a position can be renewed it checks the expiration of the previous protection to confirm that it is being renewed within the grace period.

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L181-L194>

After checking if the protection can be removed it starts the insurance at block.timestamp. The result is that the grace period doesn't collect any premium for its duration. To abuse this the user would keep renewing at the end of the grace period for the shortest amount of time so that they would get the most amount of insurance for free.

One might argue that the buyer didn't have insurance during this time but protection can be renewed at any time during the grace period and late payments are very easy to see coming (i.e. if the payment is due in 30 days and it's currently day 29). The result is that even though *technically* there isn't insurance the user is still basically insured because they would always be able to renew before a default.

### Impact

Renewal grace period can be abused to get free insurance



## Code Snippet

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L176-L195>

## Tool used

ChatGPT

## Recommendation

When renewing protection, the protection should renew from the end of the expired protection not block.timestamp.

## Discussion

**clems4ev3r**

looks like a duplicate of #179

**vnadoda**

@clems4ev3r actually this is a duplicate of #190

**clems4ev3r**

@vnadoda agreed, as per my comment on #190: #190 #308 and #179 are duplicates

**IAm0x52**

Escalate for 50 USDC

Given the yield of the sellers is directly harmed by this and there are no prerequisites for this to happen, I believe that this should be high risk. I would like to point out that #179 and #190 already categorize this as high.

**sherlock-admin**

Escalate for 50 USDC

Given the yield of the sellers is directly harmed by this and there are no prerequisites for this to happen, I believe that this should be high risk. I would like to point out that #179 and #190 already categorize this as high.

You've created a valid escalation for 50 USDC!

To remove the escalation from consideration: Delete your comment. To change the amount you've staked on this escalation: Edit your comment (**do not create a new comment**).



You may delete or edit your escalation comment anytime before the 48-hour escalation window closes. After that, the escalation becomes final.

**hrishibhat**

Escalation accepted

Considering this issue as high

**sherlock-admin**

Escalation accepted

Considering this issue as high

This issue's escalations have been accepted!

Contestants' payouts and scores will be updated according to the changes made on this issue.

**vnadoda**

@clems4ev3r @hrishibhat PR for this issue is:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/60>

**clems4ev3r**

Fix looks good



## Issue H-2: User can game protection via renewal to get free insurance

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/293>

### Found by

rvierdiiev, KingNFT, libratus, jkoppel, minhtrng, OKage, monrel, 0x52

### Summary

When renewing a position, the new protectionAmount can be higher than what was previously bought. A user can abuse this to get insurance for free. Most of the time they would keep the protection amount at 1 and pay virtually no premium. Since late payments can be seen very far in advance they would simply renew their insurance at the max value of token right before the borrower was officially late and gain the full protection.

### Vulnerability Detail

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/libraries/ProtectionPoolHelper.sol#L383-L398>

When evaluating if a user can renew their insurance only the time, token and lending contract are verified. It never checks the amount of protection that the user is renewing for. This can be abused to renew for MORE protection than originally bought. A user could abuse this to renew right before there was a late payment for the full amount of protection.

They can abuse another quirk of the renewal system to make sure they they are always able to renew at any time. Since a user is allowed to open an unlimited number of positions on a single LP token they can open a large number of positions with 1 protection amount. They would space out each protection to expire exactly with the grace period. The results it that they would be able to renew any position at a moments notice.

They would abuse this by choosing to renew their protection for the max value of the token right before a payment was officially late. This would allow them to collect a full repayment while paying basically nothing in premium.

### Impact

User can get full protection for free





## Code Snippet

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L176-L195>

## Tool used

Manual Review

## Recommendation

When renewing protection, the user should only be allowed to renew up to the value of their expired insurance

## Discussion

**vnadoda**

@clems4ev3r what's the basis for the following claim? How would a buyer know abt late payment in advance? "Since late payments can be seen very far in advance they would simply renew their insurance at the max value of token right before the borrower was officially late and gain the full protection." Cc @taisukemino

**clems4ev3r**

@clems4ev3r what's the basis for the following claim? How would a buyer know abt late payment in advance? "Since late payments can be seen very far in advance they would simply renew their insurance at the max value of token right before the borrower was officially late and gain the full protection." Cc @taisukemino

I think this is possible due to the fact that any user can go fetch lending pool status from goldfinch directly. So they are aware of state changes not yet triggered on Carapace and can adjust their positions accordingly

**vnadoda**

@clems4ev3r what's the basis for the following claim? How would a buyer know abt late payment in advance? "Since late payments can be seen very far in advance they would simply renew their insurance at the max value of token right before the borrower was officially late and gain the full protection." Cc @taisukemino

I think this is possible due to the fact that any user can go fetch lending pool status from goldfinch directly. So they are aware of state changes not yet triggered on Carapace and can adjust their positions accordingly



Yeah, buyers can't see far in the future, but even early knowledge of the late payment by a couple of hours can be exploited.

We are planning to fix this issue. @taisukemino

**vnadoda**

@clems4ev3r PR for this fix is:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/56>

when you review fix PRs, please do it in sequence, they are created as I am creating a new fix branch on top of the previous fix branch to avoid merge conflicts. Cc @hrishibhat

**clems4ev3r**

Fix looks good



## Issue H-3: Protection sellers can bypass withdrawal delay mechanism and avoid losing funds when loans are defaulted by creating withdrawal request in each cycle

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/292>

### Found by

Jeiwan, ctf\_sec, OKage, HonorLt, monrel, Allarious, Bauer, rvierdiev, chaduke, mert\_eren, XKET, ast3ros, mahdikarimi, jprod15, 0x52, libratus, immeas, KingNFT, peanuts, bin2chen, clems4ever, unforgiven, carrot, csanuragjain, Ruhum

### Summary

To prevent protection sellers from withdrawing fund immediately when protected lending pools are defaults, there is withdrawal delay mechanism, but it's possible to bypass it by creating withdraw request in each cycle by doing so user can withdraw in each cycle's open state. there is no penalty for users when they do this or there is no check to avoid this.

### Vulnerability Detail

This is `_requestWithdrawal()` code:

```
function _requestWithdrawal(uint256 _sTokenAmount) internal {
    uint256 _sTokenBalance = balanceOf(msg.sender);
    if (_sTokenAmount > _sTokenBalance) {
        revert InsufficientSTokenBalance(msg.sender, _sTokenBalance);
    }

    /// Get current cycle index for this pool
    uint256 _currentCycleIndex = poolCycleManager.getCurrentCycleIndex(
        address(this)
    );

    /// Actual withdrawal is allowed in open period of cycle after next cycle
    /// For example: if request is made in at some time in cycle 1,
    /// then withdrawal is allowed in open period of cycle 3
    uint256 _withdrawalCycleIndex = _currentCycleIndex + 2;

    WithdrawalCycleDetail storage withdrawalCycle = withdrawalCycleDetails[
        _withdrawalCycleIndex
    ];

    /// Cache existing requested amount for the cycle for the sender
```



```

uint256 _oldRequestAmount = withdrawalCycle.withdrawalRequests[msg.sender];
withdrawalCycle.withdrawalRequests[msg.sender] = _sTokenAmount;

unchecked {
    /// Update total requested withdrawal amount for the cycle considering
    ↪ existing requested amount
    if (_oldRequestAmount > _sTokenAmount) {
        withdrawalCycle.totalSTokenRequested -= (_oldRequestAmount -
            _sTokenAmount);
    } else {
        withdrawalCycle.totalSTokenRequested += (_sTokenAmount -
            _oldRequestAmount);
    }
}

emit WithdrawalRequested(msg.sender, _sTokenAmount, _withdrawalCycleIndex);
}

```

As you can see it doesn't keep track of user current withdrawal requests and user can request withdrawal for all of his balance in each cycle and by doing so user can set `withdrawalCycleDetails[Each Cycle][User]` to user's `sToken` balance. and whenever user wants to withdraw he only need to wait until the end of the current cycle while he should have waited until next cycle end.

## Impact

protection sellers can request withdraw in each cycle for their full `sToken` balance and code would allow them to withdraw in each cycle end time because code doesn't track how much of the balance of users is requested for withdrawals in the past.

## Code Snippet

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L1061-L1097>

## Tool used

Manual Review

## Recommendation

To avoid this code should keep track of user balance that is not in withdraw delay and user balance that are requested for withdraw. and to prevent users from requesting withdrawing and not doing it protocol should have some penalties for



withdrawals, for example the waiting withdraw balance shouldn't get reward in waiting duration.

## Discussion

**vnadoda**

@clems4ev3r PR for the fix is:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/63>

**clems4ev3r**

Fix looks good



## Issue H-4: Lending pool state transition will be broken when pool is expired in late state

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/230>

### Found by

rvierdiiev, Jeiwan

### Summary

Lending pool state transition will be broken when pool is expired in late state

### Vulnerability Detail

Each lending pool has its state. State is calculated inside `ReferenceLendingPools._getLendingPoolStatus` function.

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ReferenceLendingPools.sol#L318-L349>

```
function _getLendingPoolStatus(address _lendingPoolAddress)
    internal
    view
    returns (LendingPoolStatus)
{
    if (!_isReferenceLendingPoolAdded(_lendingPoolAddress)) {
        return LendingPoolStatus.NotSupported;
    }

    ILendingProtocolAdapter _adapter = _getLendingProtocolAdapter(
        _lendingPoolAddress
    );

    if (_adapter.isLendingPoolExpired(_lendingPoolAddress)) {
        return LendingPoolStatus.Expired;
    }

    if (
        _adapter.isLendingPoolLateWithinGracePeriod(
            _lendingPoolAddress,
            Constants.LATE_PAYMENT_GRACE_PERIOD_IN_DAYS
        )
    ) {

```



```

        return LendingPoolStatus.LateWithinGracePeriod;
    }

    if (_adapter.isLendingPoolLate(_lendingPoolAddress)) {
        return LendingPoolStatus.Late;
    }

    return LendingPoolStatus.Active;
}

```

Pls, note, that the first state that is checked is `expired`.

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/adapters/GoldfinchAdapter.sol#L62-L77>

```

function isLendingPoolExpired(address _lendingPoolAddress)
    external
    view
    override
    returns (bool)
{
    ICreditLine _creditLine = _getCreditLine(_lendingPoolAddress);
    uint256 _termEndTimestamp = _creditLine.termEndTime();

    /// Repaid logic derived from Goldfinch frontend code:
    /// https://github.com/goldfinch-eng/mono/blob/bd9adae6fbd810d1ebb5f7ef22df5bb_
    ↪ 6f1eaee3b/packages/client2/lib/pools/index.ts#L54
    /// when the credit line has zero balance with valid term end, it is
    ↪ considered repaid
    return
        block.timestamp >= _termEndTimestamp ||
        (_termEndTimestamp > 0 && _creditLine.balance() == 0);
}

```

As you can see, pool is expired if time of credit line has ended or loan is fully paid.

State transition for lending pool is done inside `DefaultStateManager._assessState` function. This function is responsible to lock capital, when state is late and unlock it when it's changed from late to active again.

Because the first state that is checked is `expired` there can be few problems.

First problem. Suppose that lending pool is in late state. So capital is locked. There are 2 options now: payment was done, so pool becomes active and capital unlocked, payment was not done then pool has defaulted. But in case when state is late, and lending pool expired or loan is fully repaid(so it's also becomes expired),



then capital will not be unlocked as there is no such transition Late -> Expired. The state will be changed to Expired and no more actions will be done. Also in this case it's not possible to detect if lending pool expired because of time or because no payment was done.

Second problem. Lending pool is in active state. Last payment should be done some time before `_creditLine.termEndTime()`. Payment was not done, which means that state should be changed to Late and capital should be locked, but state was checked when loan has ended, so it became Expired and again there is no such transition that can detect that capital should be locked in this case. The state will be changed to Expired and no more actions will be done.

## Impact

Depending on situation, capital can be locked forever or protection buyers will not be compensated.

## Code Snippet

Provided above

## Tool used

Manual Review

## Recommendation

These are tricky cases, think about transition for lending pool in such cases.

## Discussion

**vnadoda**

@clems4ev3r We are planning to fix this, possibly using recommendation mentioned in a duplicate #251

**clems4ev3r**

@vnadoda agreed

**vnadoda**

@clems4ev3r PR for this fix:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/65>

**clems4ev3r**

Fix looks good





## Issue H-5: Existing buyer who has been regularly renewing protection will be denied renewal even when she is well within the renewal grace period

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/174>

### Found by

OKage

### Summary

Existing buyers have an opportunity to renew their protection within grace period. If lending state update happens from `Active` to `LateWithinGracePeriod` just 1 second after a buyer's protection expires, protocol denies buyer an opportunity even when she is well within the grace period.

Since defaults are not sudden and an `Active` loan first transitions into `LateWithinGracePeriod`, it is unfair to deny an existing buyer an opportunity to renew (its alright if a new protection buyer is DOSed). This is especially so because a late loan can become `active` again in future (or move to `default`, but both possibilities exist at this stage).

All previous protection payments are a total loss for a buyer when she is denied a legitimate renewal request at the first sign of danger.

### Vulnerability Detail

`renewProtection` first calls `verifyBuyerCanRenewProtection` that checks if the user requesting renewal holds same NFT id on same lending pool address & that the current request is within grace period defined by protocol.

Once successfully verified, `renewProtection` calls `_verifyAndCreateProtection` to renew protection. This is the same function that gets called when a new protection is created.

Notice that this function calls `_verifyLendingPoolIsActive` as part of its verification before creating new protection - this check denies protection on loans that are in `LateWithinGracePeriod` or `Late` phase (see snippet below).

```
function _verifyLendingPoolIsActive(
    IDefaultStateManager defaultManager,
    address _protectionPoolAddress,
    address _lendingPoolAddress
) internal view {
    LendingPoolStatus poolStatus = defaultManager.getLendingPoolStatus(
```



```

        _protectionPoolAddress,
        _lendingPoolAddress
    );

    ...
    if (
        poolStatus == LendingPoolStatus.LateWithinGracePeriod ||
        poolStatus == LendingPoolStatus.Late
    ) {
        revert IProtectionPool.LendingPoolHasLatePayment(_lendingPoolAddress);
    }
    ...
}

```

## Impact

User who has been regularly renewing protection and paying premium to protect against a future loss event will be denied that very protection when she most needs it.

If existing user is denied renewal, she can never get back in (unless the lending pool becomes active again). All her previous payments were a total loss for her.

## Code Snippet

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L189>

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/libraries/ProtectionPoolHelper.sol#L407>

## Tool used

Manual Review

## Recommendation

When a user is calling `renewProtection`, a different implementation of `verifyLendingPoolIsActive` is needed that allows a user to renew even when lending pool status is `LateWithinGracePeriod` or `Late`.

Recommend using `verifyLendingPoolIsActiveForRenewal` function in renewal flow as shown below

```

function verifyLendingPoolIsActiveForRenewal(
    IDefaultStateManager defaultManager,

```



```

    address _protectionPoolAddress,
    address _lendingPoolAddress
) internal view {
    LendingPoolStatus poolStatus = defaultStateManager.getLendingPoolStatus(
        _protectionPoolAddress,
        _lendingPoolAddress
    );

    if (poolStatus == LendingPoolStatus.NotSupported) {
        revert IProtectionPool.LendingPoolNotSupported(_lendingPoolAddress);
    }
    //----- audit - this section needs to be commented-----//
    //if (
    //    poolStatus == LendingPoolStatus.LateWithinGracePeriod ||
    //    poolStatus == LendingPoolStatus.Late
    //) {
    //    revert IProtectionPool.LendingPoolHasLatePayment(_lendingPoolAddress);
    //}
    // -----//

    if (poolStatus == LendingPoolStatus.Expired) {
        revert IProtectionPool.LendingPoolExpired(_lendingPoolAddress);
    }

    if (poolStatus == LendingPoolStatus.Defaulted) {
        revert IProtectionPool.LendingPoolDefaulted(_lendingPoolAddress);
    }
}

```

## Discussion

**vnadoda**

@clems4ev3r, @taisukemino and I will discuss this internally

**vnadoda**

@clems4ev3r planning to fix this.

**clems4ev3r**

@vnadoda yes this is a valid issue

**Jeiwan**

@vnadoda Could you please clarify why this is a valid issue? And I'd appreciate if you share how you fixed it.

In my view, the recommended mitigation introduces a different vulnerability: allowing to renew protections in LateWithinGracePeriod and Late states gives



buyers an advantage and allows to time late positions because positions in these states have a higher chance of a default. This can be exploited as follows:

1. Buyers only buy protections with the minimal duration.
2. Expired protections are not renewed until positions get into the `LateWithinGracePeriod` or `Late` state.
3. Multiple options here: a) If positions don't get into the `LateWithinGracePeriod` state before the renewal window has expired, buyers renew positions. This allows them to not pay for the duration of the renewal window. b) When positions are in the `LateWithinGracePeriod` state and the grace period is close to running out, buyers renew their protections so that they cover the moment when the positions default. c) When positions are in the `Late` state, buyers renew their protections to cover the moment when the positions default.

This allows buyers to minimize the cost of protections while having an almost guaranteed way to get a protection if a position defaults.

#### **vnadoda**

@Jeiwan @clems4ev3r @hrishibhat Once protection is expired, buyers will have a certain time limit within which they have to renew (7-10 days). So buyers can't wait for a long time. Generally payment period for loans is 30 days. Essentially buyers have to continuously renew their protections to get the coverage.

#### **vnadoda**

@clems4ev3r PR for this fix is:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/72>

#### **clems4ev3r**

Fix looks good



## Issue H-6: Protection seller will lose unlocked capital if it fails to claim during more than one period

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/142>

### Found by

dec3ntraliz3d, VAD37, Koolex, bin2chen, MalfurionWhitehat, XKET, Tricko, immeas, jkoppel

### Summary

The protection seller will lose unlocked capital if it fails to claim during more than one period.

### Vulnerability Detail

The function `DefaultStateManager._calculateClaimableAmount`, used by `DefaultStateManager.calculateAndClaimUnlockedCapital`, which in turn is used by `ProtectionPool.claimUnlockedCapital`, overrides the claimable unlocked capital on every loop iteration on the `lockedCapitals` array.

As a result, only the last snapshot is returned by this function, regardless if the protection seller has claimed the unlocked capital or not. The purpose of this code was to prevent sellers from claiming the same snapshot twice, but since the `_claimableUnlockedCapital` variable is being overwritten instead of incremented, on each loop iteration, it will also make sellers lose unlocked capital if they fail to claim at each snapshot.

Proof of concept:

1. Pool goes to locked state with snapshotId 1
2. Pool goes to active state
3. Pool goes to locked state with snapshotId 2
4. Pool goes to active state
5. Protection seller calls `ProtectionPool.claimUnlockedCapital`, but they will only receive what's due from snapshotId 2, not from snapshotId 1

### Impact

The protection seller will lose unlocked capital if it fails to claim during more than one period.



## Code Snippet

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/DefaultStateManager.sol#L500-L505>

## Tool used

Manual Review

## Recommendation

Increment `_claimableUnlockedCapital` for all locked capital instances.

## Discussion

**vnadoda**

@clems4ev3r PR for the fix is:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/62>

**clems4ev3r**

Fix looks good



## Issue H-7: Sybil on withdrawal requests can allow leverage factor manipulation with flashloans

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/116>

### Found by

libratus, ck, clems4ever, mahdikarimi, 0x52

### Summary

To be able to withdraw, a user has to request a withdraw first. The only requirement to be able to request a withdraw is to have a balance of SToken upon requesting. By requesting withdraws with the same tokens but from different addresses, a malicious user can create the option to withdraw during one cycle more than what is deposited in the protocol. They cannot drain the protocol since they only have a limited amount of SToken to burn (required to call `withdraw()`), but they acquire the ability to deposit new funds and withdraw them in the same block, thus manipulating premium prices.

### Vulnerability Detail

Consider the following scenario: A malicious user wants to manipulate `leverageRatio` (to get a cheaper premium for example).

They deposit 10k USDC into the protocol, and get 10k STokens. They request immediately a withdraw, and transfer STokens to another address and request a withdraw there, repeating the process 10 times.

This works since balance is checked on requesting withdrawal but not locked or committed: <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L992-L995>

2 cycles later (actually ~1 cycle if the timing is optimized), they have the ability to take a flashloan for 100k USDC, deposit through the 10 addresses used, enjoy the cheaper premium as a protection buyer due to `leverageFactor` being high and withdraw all in the same transaction.

They can safely repay the flash loan.

### Impact

Protection buyers can use this to:

- game premium prices, meaning that protection sellers get ruged.



- overprotect their lending positions (used in conjunction with HIGH-02, it can drain the whole protection pool if lending pool defaults).
- DOS the protocol by sending the leverage factor very high.

## Code Snippet

## Tool used

Manual Review

## Recommendation

Freeze STokens for a depositor once they requested a withdrawal.

## Discussion

**vnadoda**

@clems4ev3r PR for the fix is:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/63>

**clems4ev3r**

Fix looks good





## Issue H-8: Protection buyer may buy multiple protections for same goldfinch NFT

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/112>

### Found by

libratus, jkoppel, ctf\_sec, bin2chen, minhtrng, modern\_Alchemist\_00, clems4ever, immeas, 0Kage, c7e7eff, chaduke, Allarious, 0x52, \_\_141345\_\_

### Summary

The Carapace protocol checks that a protection buyer does not buy a protection for an amount greater than the remainingPrincipal in the corresponding loan. However it possible for the buyer to buy multiple different protections for the same Goldfinch loan.

### Vulnerability Detail

The check for the possibility for a user to buy a protection is done here in `ReferenceLendingPools.canBuyProtection`:  
<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ReferenceLendingPools.sol#L132-L168>

It checks the protection about to be created does not cross remaining principal. But it still allows the user to create multiple protections for the same loan position.

### Impact

The malicious user can overprotect their loan position on Goldfinch and thus claim a larger amount on loan default than what they lended. For now as the default claiming feature is not implemented, they can use this bug to DOS the protocol by using all funds deposited into the protocol reaching `leverageRatioFloor` and not allowing any new protections to be bought.

### Code Snippet

#### Tool used

Manual Review

### Recommendation

Keep track of the total protection subscribed for a given loan and limit total protection value to remaining capital



## Discussion

**vnadoda**

@clems4ev3r this is duplicate of #193 & #139

**hrishibhat**

Sponsor comment from #193:

Double buying of protections for the same NFT is a known issue and we were planning to tackle it in an upcoming version because even after buying multiple protections buyers won't be able to claim for the same position as default payout will require NFT lock/transfer in the carapace vault.

This double counting of locked capital issue seems a legit concern. Now we are considering fixing this with other audit issues.

**vnadoda**

@clems4ev3r PR for this fix:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/59>

**clems4ev3r**

Fix looks good



## Issue H-9: Too many active protections can cause the ProtectionPool reach the block gas limit

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/63>

### Found by

ctf\_sec, Koolex, Tricko, 0Kage, Bauer, rvierdiev, chaduke, ast3ros, 0x52, libratus, minhtrng, MalfurionWhitehat, modern\_Alchemist\_00, yixxas, jkoppel, \_\_141345\_\_, SPYBOY, KingNFT, peanuts, bin2chen, clems4ever, unforgiven, Ruhum

### Summary

There are two instances where the ProtectionPool contract loops over an unbounded array. These can cause the transaction to succeed the block gas limit causing the transaction to revert, see <https://swcregistry.io/docs/SWC-128>.

### Vulnerability Detail

Both in `lockCapital()` and in `_accruePremiumAndExpireProtections()` the contract loops over the unbounded array of protections. If there are too many protections the transaction will revert because it reached the block gas limit.

### Impact

Both the `lockCapital()` and `_accruePremiumAndExpireProtections()` functions are critical components of the contract. Them not being accessible renders the contract useless. Protection buyers won't be covered in case of the underlying pool defaulting because the deposited tokens can't be locked up

### Code Snippet

`lockCapital()`: <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L378-L411>

`_accruePremiumAndExpireProtections()`: <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L957-L1021>

### Tool used

Manual Review



## Recommendation

You either have to limit the number of protections so that it is impossible that you surpass the block gas limit. Or, you change the logic so that you're never forced to loop over all the existing protections.

## Discussion

**vnadoda**

@clems4ev3r We are aware of this concern re: `accruePremiumAndExpireProtections` and hence we had put mitigation in place. If there are too many protections to iterate over, we can call the function `accruePremiumAndExpireProtections` in batch using `_lendingPools` param. See <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L279>

The function `lockCapital` deals with one lending pool at a time, so practically it will not have too many protections to iterate over.

**clems4ev3r**

@vnadoda `activeProtectionIndexes` is unbounded even for one `lendingPool`. Any malicious user can stuff the array by taking small protections and cause the DOS. This sounds like a valid issue

**vnadoda**

@clems4ev3r @taisukemino let's discuss possible remedies. can we set up conf call?

**vnadoda**

@clems4ev3r As discussed on the call, the following 2 fixes should reduce `lockCapital` attack vector significantly:

1. Don't allow buyers to buy protection for the same NFT/lending position multiple times
2. Introduce min protection amount param

@taisukemino let's discuss this internally.

**vnadoda**

@hrishibhat we are planning to address this

**vnadoda**

@hrishibhat @clems4ev3r Min protection amount change is NOT needed because a buyer can only buy one protection per lending position. Let me know if you have any questions/concerns.

**jacksanford1**



No code change planned, labeling as Acknowledged by protocol team



## Issue H-10: Missing validation of snapshotId makes it possible for the investor to claim unlocked capitals from the same snapshot multiple times

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/60>

### Found by

Koolex, bin2chen

### Summary

Missing validation of snapshotId makes it possible for the investor/seller to claim unlocked capitals from the same snapshot multiple times

### Vulnerability Detail

#### Description

The seller can call `ProtectionPool.claimUnlockedCapital` function to claim unlocked capitals. It then calls `defaultStateManager.calculateAndClaimUnlockedCapital` to calculate the claimable amount, then it transfers the amount to the seller if it is greater than zero. `defaultStateManager.calculateAndClaimUnlockedCapital` function works as follows:

1. Iterates over all lending pools.
2. For each lending pool calculates the claimable amount for the seller.
3. Updates the last claimed snapshot id for the seller for the given lending pool so it becomes uncalimable next time.

However, before updating the last claimed snapshot id, it doesn't check if the returned snapshot id (from `_calculateClaimableAmount` function) is zero. This means if it happens that the returned value is zero, the last claimed snapshot id will be reset to its initial value (zero) and the seller can claim again as if s/he never did.

#### PoC

Given: A pool protection with one lending pool for simplicity Seller's `lastClaimedSnapshotId` = 0

Imagine the following sequence of events:

- **Event:** Lending pool transition from **Active to Late**
  - A snapshot taken



- LockedCapitals[0].snapshotId = 1
- LockedCapitals[0].locked = true
- **Event: Lending pool transition from Late to Active**
  - LockedCapitals[0].snapshotId = 1
  - LockedCapitals[0].locked = false
- **Event: Seller claims** => receives his/her share of the unlocked capital
  - LastClaimedSnapshotId = 1
- **Event: Seller claims** => doesn't receive anything
  - LastClaimedSnapshotId = 0 (this is the issue as it is reset to zero)
- **Now the seller can claim again from the same snapshot**
- **Event: Seller claims** => receives his/her share of the unlocked capital
  - LastClaimedSnapshotId = 1

This can be repeated till all funds/capitals are drained.

This happens when all snapshots were claimed before, then the function `_calculateClaimableAmount` will return `_latestClaimedSnapshotId` as zero.

## Impact

- An investor/seller could possibly claim unlocked capitals from the same snapshot multiple times which is unfair.
- An attacker could join the pool as seller, later drains the funds from the protection pool whenever any lending pool goes into Late then Active state again.

## Code Snippet

- `ProtectionPool.claimUnlockedCapital`

```

/// Investors can claim their total share of released/unlocked capital across
↳ all lending pools
uint256 _claimableAmount = defaultStateManager
    .calculateAndClaimUnlockedCapital(msg.sender);

if (_claimableAmount > 0) {
    console.log(
        "Total sToken underlying: %s, claimableAmount: %s",
        totalSTokenUnderlying,
        _claimableAmount
    );
}

```



```

    /// transfer the share of unlocked capital to the receiver
    poolInfo.underlyingToken.safeTransfer(_receiver, _claimableAmount);
}

```

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L427-L445>

- defaultStateManager.calculateAndClaimUnlockedCapital

```

/// Calculate the claimable amount across all the locked capital instances for a
↪ given protection pool
(
    uint256 _unlockedCapitalPerLendingPool,
    uint256 _snapshotId
) = _calculateClaimableAmount(poolState, _lendingPool, _seller);
_claimedUnlockedCapital += _unlockedCapitalPerLendingPool;

/// update the last claimed snapshot id for the seller for the given
↪ lending pool,
/// so that the next time the seller claims, the calculation starts from
↪ the last claimed snapshot id
poolState.lastClaimedSnapshotIds[_lendingPool][_seller] = _snapshotId;

```

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/DefaultStateManager.sol#L186-L195>

- defaultStateManager.\_calculateClaimableAmount

```

/// Verify that the seller does not claim the same snapshot twice
if (!lockedCapital.locked && _snapshotId > _lastClaimedSnapshotId) {
    ERC20SnapshotUpgradeable _poolSToken = ERC20SnapshotUpgradeable(
        address(poolState.protectionPool)
    );

    console.log(
        "balance of seller: %s, total supply: %s at snapshot: %s",
        _poolSToken.balanceOfAt(_seller, _snapshotId),
        _poolSToken.totalSupplyAt(_snapshotId),
        _snapshotId
    );

    /// The claimable amount for the given seller is proportional to the seller's
    ↪ share of the total supply at the snapshot
    /// claimable amount = (seller's snapshot balance / total supply at snapshot)
    ↪ * locked capital amount
    _claimableUnlockedCapital =
        (_poolSToken.balanceOfAt(_seller, _snapshotId) *

```





```

        lockedCapital.amount) /
        _poolSToken.totalSupplyAt(_snapshotId);

    /// Update the last claimed snapshot id for the seller
    _latestClaimedSnapshotId = _snapshotId;

    console.log(
        "Claimable amount for seller %s is %s",
        _seller,
        _claimableUnlockedCapital
    );
}

```

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/DefaultStateManager.sol#L487-L515>

## Tool used

Manual Review

## Recommendation

Only update the last snapshot id of the seller if it is greater than zero.

Example:

```

if(_snapshotId > 0){
    poolState.lastClaimedSnapshotIds[_lendingPool][_seller] = _snapshotId;
}

```

## Discussion

**vnadoda**

@clems4ev3r this isn't a valid concern/issue. The function `DefaultStateManager._calculateClaimableAmount` always starts with the seller's last claimed snapshot id and not with 0. So in the scenario/PoC mentioned, when the seller tries to claim a second time, returned `_latestClaimedSnapshotId` will be 1 and not 0.

See: <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/DefaultStateManager.sol#L466>

**clems4ev3r**

@vnadoda surprisingly this seems valid.



After a user has claimed for a snapshot, latest snapshot claimed is correctly set here: <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/DefaultStateManager.sol#L195>

If the user calls the function again, they will be able to claim zero funds since the condition here is always false: <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/DefaultStateManager.sol#L488>

Unfortunately that means the variable `_latestClaimedSnapshotId` is not set here: <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/DefaultStateManager.sol#L508>

and so `_calculateClaimableAmount` returns a `_latestClaimedSnapshotId == 0` resetting latest claimed snapshot and user can claim again

**vnadoda**

@clems4ev3r ah, I see it now. var at the beginning is `_lastClaimedSnapshotId` is different than return var `_latestClaimedSnapshotId`. I will add this to the fix list

**vnadoda**

@clems4ev3r PR for this fix is: <https://github.com/carapace-finance/credit-default-swaps-contracts/pull/55>

**clems4ev3r**

Fix looks good



## Issue H-11: Malicious seller forced break lockCapital()

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/31>

### Found by

bin2chen, clems4ever

### Summary

Malicious burn nft causes failure to lockCapital() seller steady earn PremiumAmount, buyer will be lost compensation

### Vulnerability Detail

When the status of the lendingPool changes from Active to Late, the protocol will call ProtectionPool.lockCapital() to lock amount lockCapital() will loop through the active protections to calculate the lockedAmount. The code is as follows:

```
function lockCapital(address _lendingPoolAddress)
    external
    payable
    override
    onlyDefaultStateManager
    whenNotPaused
    returns (uint256 _lockedAmount, uint256 _snapshotId)
{
    ....
    uint256 _length = activeProtectionIndexes.length();
    for (uint256 i; i < _length; ) {
        ...
        uint256 _remainingPrincipal = poolInfo
            .referenceLendingPools
            .calculateRemainingPrincipal(                //<----- calculate
↳ Remaining Principal
            _lendingPoolAddress,
            protectionInfo.buyer,
            protectionInfo.purchaseParams.nftLpTokenId
        );
    }
}
```

The important thing inside is to calculate the \_remainingPrincipal by referenceLendingPools.calculateRemainingPrincipal()

```
function calculateRemainingPrincipal(
    address _lendingPoolAddress,
    address _lender,
```



```

    uint256 _nftLpTokenId
) public view override returns (uint256 _principalRemaining) {
...

    if (_poolTokens.ownerOf(_nftLpTokenId) == _lender) {    //<-----call
↳ ownerOf()
        IPoolTokens.TokenInfo memory _tokenInfo = _poolTokens.getTokenInfo(
            _nftLpTokenId
        );

    ....

    if (
        _tokenInfo.pool == _lendingPoolAddress &&
        _isJuniorTrancheId(_tokenInfo.tranche)
    ) {
        _principalRemaining =
            _tokenInfo.principalAmount -
            _tokenInfo.principalRedeemed;
    }
}
}
}

```

GoldfinchAdapter.calculateRemainingPrincipal() The current implementation will first determine if the ownerOf the NFTID is \_lender

There is a potential problem here, if the NFTID has been burned, the ownerOf() will be directly revert, which will lead to calculateRemainingPrincipal() revert, and lockCapital() revert and can't change status from active to late

Let's see whether Goldfinch's implementation supports burn(NFTID), and whether ownerOf(NFTID) will revert

1. PoolTokens has burn() method , if principalRedeemed==principalAmount you can burn it

```

contract PoolTokens is IPoolTokens, ERC721PresetMinterPauserAutoIdUpgradeSafe,
↳ HasAdmin, IERC2981 {
    ....

    function burn(uint256 tokenId) external virtual override whenNotPaused {
        TokenInfo memory token = _getTokenInfo(tokenId);
        bool canBurn = _isApprovedOrOwner(_msgSender(), tokenId);
        bool fromTokenPool = _validPool(_msgSender()) && token.pool == _msgSender();
        address owner = ownerOf(tokenId);
        require(canBurn || fromTokenPool, "ERC721Burnable: caller cannot burn this
↳ token");
        require(token.principalRedeemed == token.principalAmount, "Can only burn
↳ fully redeemed tokens");
        _destroyAndBurn(tokenId);
    }
}

```



```
    emit TokenBurned(owner, token.pool, tokenId);  
}
```

<https://github.com/goldfinch-eng/mono/blob/88f0e3f94f6dd23ebae429fe09e2511650df893a/packages/protocol/contracts/protocol/core/PoolTokens.sol#L199>

2.ownerOf() if nftid don't exists will revert with message "ERC721: owner query for nonexistent token"

```
contract ERC721UpgradeSafe is  
    Initializable,  
    ContextUpgradeSafe,  
    ERC165UpgradeSafe,  
    IERC721,  
    IERC721Metadata,  
    IERC721Enumerable  
{  
    ...  
    function ownerOf(uint256 tokenId) public view override returns (address) {  
        return _tokenOwners.get(tokenId, "ERC721: owner query for nonexistent  
→ token");  
    }  
}
```

<https://github.com/goldfinch-eng/mono/blob/88f0e3f94f6dd23ebae429fe09e2511650df893a/packages/protocol/contracts/external/ERC721.sol#L136-L138>

If it can't changes to late, Won't lock the fund, seller steady earn PremiumAmount

So there are two risks

1. normal buyer gives NFTID to burn(), he does not know that it will affect all protection of the lendingPool
2. Malicious seller can buy a protection first, then burn it, so as to force all protection of the lendingPool to expire and get the PremiumAmount maliciously. buyer unable to obtain compensation

Suggested try catch for \_poolTokens.ownerOf() If revert, it is assumed that the lender is not the owner

## Impact

buyer will be lost compensation

## Code Snippet

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L389-L395>



<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/adapters/GoldfinchAdapter.sol#L162-L165>

## Tool used

Manual Review

## Recommendation

try catch for `_poolTokens.ownerOf()` If revert, it is assumed that the lender is not the owner

## Discussion

**vnadoda**

@clems4ev3r Fix for this issue:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/64>

**clems4ev3r**

Fix looks good



## Issue H-12: Sandwich attack to accruePremiumAndExpireProtections()

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/26>

### Found by

libratus, jkoppel, immeas, OKage, chaduke, monrel

### Summary

`accruePremiumAndExpireProtections()` will increase `totalSTokenUnderlying`, and thus increase the exchange rate of the `ProtectionPool`. A malicious user can launch a sandwich attack and profit. This violates the Fair Distribution principle of the protocol: <https://www.carapace.finance/WhitePaper#premium-pricing>

### Vulnerability Detail

Let's show how a malicious user, Bob, can launch a sandwich attack to `accruePremiumAndExpireProtections()` and profit.

1. Suppose there are 1,000,000 underlying tokens for the `ProtectionPool`, and `totalSupply` = 1,000,000, therefore the exchange rate is 1/1 share. Suppose Bob has 100,000 shares.
2. Suppose `accruePremiumAndExpireProtections()` is going to be called and add 100,000 to `totalSTokenUnderlying` at L346.

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L279-L354>

- 3) Bob front-runs `accruePremiumAndExpireProtections()` and calls `deposit()` to deposit 100,000 underlying tokens into the contract. The check for `ProtectionPoolPhase` will pass for an open phase. As a result, there are 1,100,000 underlying tokens, and 1,100,000 shares, the exchange rate is still 1/1 share. Bob now has 200,000 shares.

```
function deposit(uint256 _underlyingAmount, address _receiver)
    external
    override
    whenNotPaused
    nonReentrant
{
    _deposit(_underlyingAmount, _receiver);
}

function _deposit(uint256 _underlyingAmount, address _receiver) internal {
```



```

    /// Verify that the pool is not in OpenToBuyers phase
    if (poolInfo.currentPhase == ProtectionPoolPhase.OpenToBuyers) {
        revert ProtectionPoolInOpenToBuyersPhase();
    }

    uint256 _sTokenShares = convertToSToken(_underlyingAmount);
    totalSTokenUnderlying += _underlyingAmount;
    _safeMint(_receiver, _sTokenShares);
    poolInfo.underlyingToken.safeTransferFrom(
        msg.sender,
        address(this),
        _underlyingAmount
    );

    /// Verify leverage ratio only when total capital/sTokenUnderlying is higher
    ↪ than minimum capital requirement
    if (_hasMinRequiredCapital()) {
        /// calculate pool's current leverage ratio considering the new deposit
        uint256 _leverageRatio = calculateLeverageRatio();

        if (_leverageRatio > poolInfo.params.leverageRatioCeiling) {
            revert ProtectionPoolLeverageRatioTooHigh(_leverageRatio);
        }
    }

    emit ProtectionSold(_receiver, _underlyingAmount);
}

```

- 4) Now `accruePremiumAndExpireProtections()` gets called and 100,000 is added to `totalSTokenUnderlying` at L346. As a result, we have 1,200,000 underlying tokens with 1,100,000 shares. The exchange rate becomes 12/11 share.
- 5) Bob calls the `withdraw()` function (assume he made a request two cycles back, he could do that since he had 100,000 underlying tokens in the pool) to withdraw 100,000 shares and he will get  $100,000 \times \frac{12}{11} = 109,090$  underlying tokens. So he has a profit of 9,090 underlying tokens by the sandwich attack.

## Impact

A malicious user can launch a sandwich attack to `accruePremiumAndExpireProtections()` and profit.

## Code Snippet

See above





## Tool used

VScode

Manual Review

## Recommendation

- Create a new contract as a temporary place to store the accrued premium, and then deliver it to the `ProtectionPool` over a period of time (delivery period) with some `premiumPerSecond` to lower the incentive of a quick profit by sandwich attack.
- Restrict the maximum deposit amount for each cycle.
- Restrict the maximum withdraw amount for each cycle.

## Discussion

**vnadoda**

@clems4ev3r this is a duplicate of #294 and #204

**vnadoda**

@clems4ev3r can you verify this is a duplicate? @hrishibhat can we close this?

**clems4ev3r**

@vnadoda agreed, this is a duplicate of #294 and #204

**vnadoda**

@hrishibhat please close this.

**vnadoda**

@clems4ev3r PR for this fix:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/57>

**clems4ev3r**

Fix looks good



## Issue M-1: function lockCapital() doesn't filter the expired protections first and code may lock more funds than required and expired defaulted protections may funded

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/305>

### Found by

rvierdiiev, Web3SecurityDAO, unforgiven, XKET, \_\_141345\_\_

### Summary

when a lending loan defaults, then function lockCapital() get called in the ProtectionPool to lock required funds for the protections bought for that lending pool, but code doesn't filter the expired protections first and they may be expired protection in the active protection array that are not excluded and this would cause code to lock more fund and pay fund for expired defaulted protections and protection sellers would lose more funds.

### Vulnerability Detail

This lockCapital() code:

```
function lockCapital(address _lendingPoolAddress)
    external
    payable
    override
    onlyDefaultStateManager
    whenNotPaused
    returns (uint256 _lockedAmount, uint256 _snapshotId)
{
    /// step 1: Capture protection pool's current investors by creating a snapshot
    ↪ of the token balance by using ERC20Snapshot in SToken
    _snapshotId = _snapshot();

    /// step 2: calculate total capital to be locked
    LendingPoolDetail storage lendingPoolDetail = lendingPoolDetails[
        _lendingPoolAddress
    ];

    /// Get indexes of active protection for a lending pool from the storage
    EnumerableSetUpgradeable.UintSet
    storage activeProtectionIndexes = lendingPoolDetail
        .activeProtectionIndexes;
```



```

    /// Iterate all active protections and calculate total locked amount for this
    ↪ lending pool
    /// 1. calculate remaining principal amount for each loan protection in the
    ↪ lending pool.
    /// 2. for each loan protection, lockedAmt = min(protectionAmt,
    ↪ remainingPrincipal)
    /// 3. total locked amount = sum of lockedAmt for all loan protections
    uint256 _length = activeProtectionIndexes.length();
    for (uint256 i; i < _length; ) {
        /// Get protection info from the storage
        uint256 _protectionIndex = activeProtectionIndexes.at(i);
        ProtectionInfo storage protectionInfo = protectionInfos[_protectionIndex];

        /// Calculate remaining principal amount for a loan protection in the
    ↪ lending pool
        uint256 _remainingPrincipal = poolInfo
            .referenceLendingPools
            .calculateRemainingPrincipal(
                _lendingPoolAddress,
                protectionInfo.buyer,
                protectionInfo.purchaseParams.nftLpTokenId
            );

        /// Locked amount is minimum of protection amount and remaining principal
        uint256 _protectionAmount = protectionInfo
            .purchaseParams
            .protectionAmount;
        uint256 _lockedAmountPerProtection = _protectionAmount <
            _remainingPrincipal
            ? _protectionAmount
            : _remainingPrincipal;

        _lockedAmount += _lockedAmountPerProtection;

        unchecked {
            ++i;
        }
    }

    unchecked {
        /// step 3: Update total locked & available capital in storage
        if (totalSTokenUnderlying < _lockedAmount) {
            /// If totalSTokenUnderlying < _lockedAmount, then lock all available
    ↪ capital
            _lockedAmount = totalSTokenUnderlying;
            totalSTokenUnderlying = 0;
        } else {
            /// Reduce the total sToken underlying amount by the locked amount

```



```
        totalSTokenUnderlying -= _lockedAmount;  
    }  
}  
}
```

As you can see code loops through active protection array for that lending pool and calculates required locked amount but it doesn't call `_accruePremiumAndExpireProtections()` to make sure active protections doesn't include any expired protections. if function `_accruePremiumAndExpireProtections()` doesn't get called for a while, then there would be possible that some of the protections are expired and they are still in the active protection array. This would cause code to calculated more locked amount and also pay fund for those expired defaulted protections too from protection sellers. (also when calculating the required token payment for the protection code doesn't check the expiration too in the other functions that are get called by the `lockCapital()`, the expire check doesn't exists in inner function too)

## Impact

see summery

## Code Snippet

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L357-L411>

## Tool used

Manual Review

## Recommendation

call `_accruePremiumAndExpireProtections()` for the defaulted pool to filter out the expired protections.

## Discussion

**vnadoda**

@clems4ev3r we plan to fix this issue

**vnadoda**

@clems4ev3r PR for this issue:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/68>

**clems4ev3r**



Fix looks good



## Issue M-2: Protection can be bought in late pools, allowing buyers to pay minimal premium and increase the chance of a compensation

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/252>

### Found by

rvierdiiev, libratus, Jeiwan, ctf\_sec, Kumpa, ast3ros, mahdikarimi, OKage, monrel, Allarious

### Summary

A buyer can buy a protection for a pool that's already late on a payment. The buyer can pay the minimal premium and get a higher chance of getting a compensation. Protection sellers may bear higher losses due to reduced premium amounts and the increased chance of protection payments.

### Vulnerability Detail

The protocol allows lenders on Goldfinch to get an insurance on the funds they lent. The insurance is paid after a repayment was late. The protocol doesn't allow protection buyers to buy protections for pools that's already late to disallow buyers abusing the protections payment mechanism. To do this, the `_verifyLendingPoolIsActive` function checks the current status of a pool and reverts if it's late.

However, `poolStatus` is cached and can be outdated when the function is called, since it's not updated in the call. Pool statuses are updated in `assessStates` and `assessStateBatch`, which are triggered on schedule separately. This allows buyers to buy protections in pools that's already late in Goldfinch but still active in Carapace.

Consider this scenario:

1. A pool is in the active state after `assessStates` is run.
2. Before the next `assessStates` call, the pool gets into the late state, due to a missed repayment. However, in the protocol, the pool is still in the active state since `assessStates` hasn't been called.
3. The malicious buyer front runs the next `assessStates` call and submits their transactions that buys a protection with the minimal duration for the pool. The `_verifyLendingPoolIsActive` function passes because the pool's state hasn't been updated in the contracts yet.
4. The `assessStates` call changes the status of the pool to `LateWithinGracePeriod`, which disallows buying protections for the pool.



5. If the pool eventually gets into the default state (chances of that is higher since there's already a late payment), the malicious buyer will be eligible for a compensation.

## Impact

Protection buyers can increase their chances of getting a compensation, while buying protections with the minimal duration and paying the minimal premium. Protection sellers will bear increased losses due to reduced premium amounts and the increased chance of a compensation.

## Code Snippet

1. `_verifyLendingPoolIsActive` checks the current status of a pool and reverts if it's not active: [ProtectionPoolHelper.sol#L412-L415](#)
2. Pool statuses are cached and are stored in `DefaultStateManager`: [DefaultStateManager.sol#L278-L280](#)
3. Pool statuses are updated in `DefaultStateManager.assessStates`: [DefaultStateManager.sol#L119](#)
4. `DefaultStateManager.assessStates` is not called by `ProtectionPool.buyProtection`: [ProtectionPool.sol#L162](#)

## Tool used

Manual Review

## Recommendation

In `ProtectionPoolHelper._verifyLendingPoolIsActive`, consider calling `DefaultStateManager._assessState` to update the status of the pool for which a protection is bought.

## Discussion

**vnadoda**

@clems4ev3r PR for this issue:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/67>

**clems4ev3r**

Fix #67 and #71 looks good



## Issue M-3: If unlocked capital in pool falls below minRequiredCapital, then protection can be bought for minimum premium

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/211>

### Found by

jkoppel

### Summary

If the unlocked capital in a pool falls below the minRequiredCapital, then protection can be bought for minimum premium

### Vulnerability Detail

In PremiumCalculator.calculatePremium, we see that if the risk factor "cannot be calculated," it uses the minimum premium.

```
if (
  RiskFactorCalculator.canCalculateRiskFactor(
    _totalCapital,
    _leverageRatio,
    _poolParameters.leverageRatioFloor,
    _poolParameters.leverageRatioCeiling,
    _poolParameters.minRequiredCapital
  )
) {
  ...
} else {
  /// This means that the risk factor cannot be calculated because of either
  /// min capital not met or leverage ratio out of range.
  /// Hence, the premium is the minimum premium
  _isMinPremium = true;
}
```

In RiskFactor.canCalculateRiskFactor, we see there are three conditions when this is so:

```
function canCalculateRiskFactor(
  uint256 _totalCapital,
  uint256 _leverageRatio,
  uint256 _leverageRatioFloor,
  uint256 _leverageRatioCeiling,
```





```

uint256 _minRequiredCapital
) external pure returns (bool _canCalculate) {
    if (
        _totalCapital < _minRequiredCapital ||
        _leverageRatio < _leverageRatioFloor ||
        _leverageRatio > _leverageRatioCeiling
    ) {
        _canCalculate = false;
    } else {
        _canCalculate = true;
    }
}
}

```

If the leverage ratio is above the ceiling, then protection should be very cheap, and it is correct to use the minimum premium. If the leverage ratio is above the floor, then protection cannot be purchased.

However, we see that the minimum premium is also used if `_totalCapital` is below `_minRequiredCapital`. In this case, protection should be very expensive, but it will instead be very cheap.

Total capital can fall this low in a couple ways. One way is if most sellers withdraw their funds and most protection positions expire. Then the pool can have a very small amount of capital while still having a leverage ratio within the window. Another is if most of the capital is locked. In that case, the protection likely cannot be bought because the leverage ratio is likely to be too low. However, when capital is locked, the corresponding protection should not count against the leverage ratio, as that can prevent buyers from buying protection even when the pool is very well capitalized ( see <https://github.com/sherlock-audit/2023-02-carapace-jkoppel/issues/11> ). If that issue is fixed, then this issue can appear when capital is locked.

## Impact

Buyers can get very cheap protection at a time when it should be expensive.

## Code Snippet

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/PremiumCalculator.sol#L63>

## Tool used

Manual Review



## Recommendation

Prohibit protection purchases when capital falls below the minimum required capital

## Discussion

**jkoppel**

Escalate for 26 USDC

This is not a duplicate of #325. That issue only talks about when the leverage ratio falls below the floor. As @clems4ev3r pointed out, that case is correctly handled: protection cannot be purchased at all.

This report talks about when the leverage ratio is within range but most funds are either withdrawn or locked. Then protection should be very expensive but is instead very cheap. And this will not revert.

**sherlock-admin**

Escalate for 26 USDC

This is not a duplicate of #325. That issue only talks about when the leverage ratio falls below the floor. As @clems4ev3r pointed out, that case is correctly handled: protection cannot be purchased at all.

This report talks about when the leverage ratio is within range but most funds are either withdrawn or locked. Then protection should be very expensive but is instead very cheap. And this will not revert.

You've created a valid escalation for 26 USDC!

To remove the escalation from consideration: Delete your comment. To change the amount you've staked on this escalation: Edit your comment **(do not create a new comment)**.

You may delete or edit your escalation comment anytime before the 48-hour escalation window closes. After that, the escalation becomes final.

**Evert0x**

Escalation accepted

**sherlock-admin**

Escalation accepted

This issue's escalations have been accepted!

Contestants' payouts and scores will be updated according to the changes made on this issue.

**vnadoda**



@clems4ev3r Fix for this issue:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/76>

**clems4ev3r**

Fix looks good



## Issue M-4: Protection too expensive when some capital is locked

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/208>

### Found by

jkoppel

### Summary

The leverage ratio is computed as a ratio of unlocked capital to total protections. This means that each protection position which has locked capital is effectively counted twice: once to lock up capital, and once again to decrease the leverage ratio. This can lead to situations where a pool is very well capitalized to sell more protection, but cannot do so.

### Vulnerability Detail

Consider: Pool has \$1.1 million in deposits, and \$1 million in protection positions. All pools have late payments, and so \$1 million is locked. Pool now has \$100k in unallocated deposits, but its leverage ratio is  $100k/1.1M \sim 0.09$ . Depending on the leverage floor, protection will either be really expensive or cannot be bought at all, even though the pool is well-capitalized.

Compare: If all pools defaulted and the \$1M was lost, then the pool would have \$100k in deposits and \$0 in protection positions, and protection would be very cheap. The situation with locked capital should be treated similarly.

### Impact

Protection is very expensive or impossible in some situations where it should be cheap.

### Code Snippet

Note that `lockCapital()` decreases `totalSTokenUnderlying` but does not modify `totalProtections`. These are the two variables used to compute the leverage ratio. See <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L357>

### Tool used

Manual Review



## Recommendation

Do not count protections which are locking up capital when computing the leverage ratio.

## Discussion

**vnadoda**

@taisukemino Please review this issue and we can discuss it.

**vnadoda**

@clems4ev3r we plan to fix this issue

**clems4ev3r**

@vnadoda agreed this is valid. Active protections which have contributed to locking capital should not be accounted for in leverage ratio

**vnadoda**

@clems4ev3r PR for this issue:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/70>

**clems4ev3r**

Fix looks good



## Issue M-5: If a `lendingPool` is added to the network while in `late` state, can be defaulted instantly

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/151>

### Found by

Allarious

### Summary

If a lending pool is added to a protection pool, the `defaultStateManager` sets the `currentState` to `late` without setting the late timestamp. This can enable anyone in the network to be able to call the `_assessState` once more and mark the pool as default.

### Vulnerability Detail

`defaultStateManager` user `_assessState` function to transfer between states. However, in case an underlying pool is called by `_assessState` for the first time when it is added to the protocol. The `_assessState` function sets the `currentState` to `late` without updating the `lateTimestamp` which will remain zero. The attacker can exploit this to move the pool to the default state where it locks the lending pool and renders it unusable.

While it is checked that when pools are added to the `ReferenceLendingPool` inside `_addReferenceLendingPool` that the pools should be in `Active` state, if in the time between the addition of a pool and the first time call of `_assessState` the pool goes from `Active` to `Late`, this attack can be performed by the attacker.

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/DefaultStateManager.sol#L370-L375>

### Impact

An attacker can render an underlying lending pool unusable.

### Code Snippet

### Tool used

Manual Review

### Recommendation

The `_assessState` should handle the initial setting of the state separately.



## Discussion

**clems4ev3r**

@vnadoda a lending pool cannot be added without being in the active state per this check: <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ReferenceLendingPools.sol#L284> this sounds invalid

**vnadoda**

@clems4ev3r A reporter has mentioned that, but his main concern is the following: "While it is checked that when pools are added to the ReferenceLendingPool inside `_addReferenceLendingPool` that the pools should be in Active state, **if in the time between the addition of a pool and the first time call of `_assessState` the pool goes from Active to Late, this attack can be performed by the attacker.**"

So I think this concern is valid, but low priority because the probability of this happening is very low.

**vnadoda**

@clems4ev3r We are planning to call `DefaultStateManager.assessState` just after adding the lending pool in `op script`. But maybe we should have `addLendingPool` in `DefaultStateManager` for `onlyOwner`, which should call `RLP.add` and then `asset state` as well? In any case, this is a low-priority issue, do you agree?

**clems4ev3r**

@vnadoda as discussed on call, given the steps taken during `op script`, and low probability of the issue this could be lowered in severity to low

**hrishibhat**

Considering this issue as low based on the comments above.

**Allarious**

Escalate for 75 USDC

The issue is pointing out that while pools get checked to be active when they are being added to the pool, they are not getting checked first time that they are undergoing the `assessState` call. This is a simple issue in nature which is incorrectly handled by the protocol that can lead to an incorrect lending pool state. Relying so heavily on `assessState` running at the same time each day can not be a good design choice and we see here that for every hour of delay, the pool is risking the default of underlying pools. Therefore, this should definitely be considered for at least medium severity. While the issue is explaining the simple attack well enough, here is a more extensive version of explanation.

This issue arises from two valid points that happen in the system:

- `assessState` gets called daily.



- The `defaultStateManager` does not handle `Not Supported` -> `Late`.

The protocol expects `addProtocol` and `assessState` to happen together, which might make sense from the developer point of view, but opens up a serious attack vector from security point of view when protocol is running `assessState` once a day.

Also, naming could be changed to "If a `lendingPool` is added to the network while **close to** late state, can be defaulted instantly". I agree that writing and the naming could be much better but the issue is pointing out a valid problem.

## Step by Step

(1) A pool in its active state gets added to the pool by calling `_addReferenceLendingPool` (2) Lets imagine the case where the daily `assessState` was just called (3) The `lendingPool` goes from `Active` -> `Late` before next `assessState` (4) In case where `assessState` is called the next day with any delay, the protocol will pass the grace period and enter the `Late` state. The protocol is not designed to handle this case, if the grace period was any smaller than one day, this issue could have caused much more damage. (5) When `assessState` is called, the `defaultStateManager` takes the system from `Not supported` -> `Late` without setting the `lateTimestamp`. (6) Any attacker in the system can call the `assessState` again to wrongfully default the pool

## Justification of this issue being H/M

- (Considerable Probability) The probability of the pool going from `Active` -> `Late` within two `assessStates` are very high, however, the protocol is heavily relying on the `assessState` being run at the same time everyday and can be extremely dangerous. If we consider a pool's payment period is 14 days, possibility of a added pool to be instantly defaulted is  $(\text{number\_of\_delay\_hours}/24) * 1/14$ , where for 6 hours of delay in running `assessState`, puts one out of roughly 50 added pools in danger of default.
- (No Permission Needed) Anyone in the network can trigger the default, and have time as far as the underlying pool is at `late` state
- (No Fees) Attacker needs to only pay the gas fee in order to cause the pool to default
- (Complete DoS) The defaulted pool is unusable and can not be removed from the `referenceLendingPools` and would be marked defaulted, effectively DoSing the buyers of the defaulted pool.
- (Inevitability) Lets imagine you run the script between 12:00 pm and 01:00 pm each day and therefore you have around 15 minutes delay time on average in 90 days, you will have an overall of 22.5 hours overall delay and if we consider the probability uniform, the change of default of pools is  $(22.5/24) * 1/\text{active\_period\_in\_days}$  which is very close to  $1/\text{active\_period\_in\_days}$ . if





`active_period_in_days = 14` then you have one out of 14 default because of this.

The issue is already showing sufficient data about the exploit, why it happens and how to stop it. Therefore, I think it should be labelled Medium or High.

## Comments provided by LSW and Sponsor

@vnadoda a lending pool cannot be added without being in the active state per this check: <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ReferenceLendingPools.sol#L284> this sounds invalid

This issue is talking about when the pool is assessed for the first time while in the `late` state. While I agree that the naming and writing could be better, it is still showing enough data if you read all of the issue carefully.

So I think this concern is valid, but low priority because the probability of this happening is very low.

The probability is considerable, as shown above. It is not a good idea to be relying on a script running everyday without no pre-cautions, now that we can see even hours late can cause some pools to default. Handling such cases on-chain would happen easily by correctly implementing `Not Supported -> Late` in `defaultStateManager`, while it is not handled correctly, should be heavily considered by the team.

We are planning to call `DefaultStateManager.assessState` just after adding the lending pool in `op` script.

If there is a need to handle this in a script/third contract, then it means there is a valid bug here. As stated in the initial scope of the audit, `assessState` gets called daily and `_addReferenceLendingPool` can be called anytime. I believe the issue's severity should be judged based on `assessState` running daily. However, if you want to use an external script/contract to handle this, you need to consider the points mentioned below.

- Either you are using a third smart contract to call `_addReferenceLendingPool` and `assessState` atomically, which is the safest option.
- Or you are using an off-chain script to send two transactions `_addReferenceLendingPool` and `assessState` together, where in this case, if the transactions are not included in the certain order of `_addReferenceLendingPool` first and `assessState` second, the `assessState` would be ineffective and attack is again valid.

**sherlock-admin**

Escalate for 75 USDC



The issue is pointing out that while pools get checked to be active when they are being added to the pool, they are not getting checked first time that they are undergoing the `assessState` call. This is a simple issue in nature which is incorrectly handled by the protocol that can lead to an incorrect lending pool state. Relying so heavily on `assessState` running at the same time each day can not be a good design choice and we see here that for every hour of delay, the pool is risking the default of underlying pools. Therefore, this should definitely be considered for at least medium severity. While the issue is explaining the simple attack well enough, here is a more extensive version of explanation.

This issue arises from two valid points that happen in the system:

- `assessState` gets called daily.
- The `defaultStateManager` does not handle `Not Supported` -> `Late`.

The protocol expects `addProtocol` and `assessState` to happen together, which might make sense from the developer point of view, but opens up a serious attack vector from security point of view when protocol is running `assessState` once a day.

Also, naming could be changed to "If a `lendingPool` is added to the network while **close to** late state, can be defaulted instantly". I agree that writing and the naming could be much better but the issue is pointing out a valid problem.

## Step by Step

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## Justification of this issue being H/M

- (Considerable Probability) The probability of the pool going from `Active` -> `Late` within two `assessStates` are very high, however, the protocol is heavily relying on the `assessState` being run at the same time everyday and can be extremely dangerous. If we consider a



pool's payment period is 14 days, possibility of a added pool to be instantly defaulted is  $(\text{number\_of\_delay\_hours}/24) * 1/14$ , where for 6 hours of delay in running `assessState`, puts one out of roughly 50 added pools in danger of default.

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- (Inevitability) Lets imagine you run the script between 12:00 pm and 01:00 pm each day and therefore you have around 15 minutes delay time on average in 90 days, you will have an overall of 22.5 hours overall delay and if we consider the probability uniform, the change of default of pools is  $(22.5/24) * 1/\text{active\_period\_in\_days}$  which is very close to  $1/\text{active\_period\_in\_days}$ . if `active\_period\_in\_days` = 14 then you have one out of 14 default because of this.

The issue is already showing sufficient data about the exploit, why it happens and how to stop it. Therefore, I think it should be labelled Medium or High.

### Comments provided by LSW and Sponsor

@vnadoda a lending pool cannot be added without being in the active state per this check: <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ReferenceLendingPools.sol#L284> this sounds invalid

This issue is talking about when the pool is assessed for the first time while in the `late` state. While I agree that the naming and writing could be better, it is still showing enough data if you read all of the issue carefully.

So I think this concern is valid, but low priority because the probability of this happening is very low.

The probability is considerable, as shown above. It is not a good idea to be relying on a script running everyday without no pre-cautions, now that we can see even hours late can cause some pools to default. Handling such cases on-chain would happen easily by correctly implementing `Not Supported -> Late` in `defaultStateManager`, while it is not handled correctly, should be heavily considered by the team.



We are planning to call `DefaultStateManager.assessState` just after adding the lending pool in op script.

If there is a need to handle this in a script/third contract, then it means there is a valid bug here. As stated in the initial scope of the audit, `assessState` gets called daily and `_addReferenceLendingPool` can be called anytime. I believe the issue's severity should be judged based on `assessState` running daily. However, if you want to use an external script/contract to handle this, you need to consider the points mentioned below.

- Either you are using a third smart contract to call `_addReferenceLendingPool` and `assessState` atomically, which is the safest option.
- Or you are using an off-chain script to send two transactions `_addReferenceLendingPool` and `assessState` together, where in this case, if the transactions are not included in the certain order of `_addReferenceLendingPool` first and `assessState` second, the `assessState` would be ineffective and attack is again valid.

You've created a valid escalation for 75 USDC!

To remove the escalation from consideration: Delete your comment. To change the amount you've staked on this escalation: Edit your comment **(do not create a new comment)**.

You may delete or edit your escalation comment anytime before the 48-hour escalation window closes. After that, the escalation becomes final.

### hrishibhat

Escalation accepted

Based on internal discussions with the Team and the Lead Watson, the protocol calls for `assessstate` as soon as the lending pool is added, but this information was not available during the audit, there is a likely chance the issue could still happen, hence considering this a valid medium.

### sherlock-admin

Escalation accepted

Based on internal discussions with the Team and the Lead Watson, the protocol calls for `assessstate` as soon as the lending pool is added, but this information was not available during the audit, there is a likely chance the issue could still happen, hence considering this a valid medium.

This issue's escalations have been accepted!



Contestants' payouts and scores will be updated according to the changes made on this issue.

**vnadoda**

@clems4ev3r fix for this issue:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/74>

**clems4ev3r**

Fix looks good



## Issue M-6: secondary markets are problematic with how lockCapital works

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/147>

### Found by

charlesjhongc, immeas

### Summary

Seeing that a pool is about to lock, an attacker can use a flash loan from a secondary market like uniswap to claim the share of a potential unlock of capital later.

### Vulnerability Detail

The timestamp a pool switches to Late can be predicted and an attacker can use this to call `assessState` which is callable by anyone. This will trigger the pool to move from `Active/LateWithinGracePeriod` to `Late` calling `lockCapital` on the `ProtectionPool`:

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L365-L366>

```
File: ProtectionPool.sol
```

```
365:    /// step 1: Capture protection pool's current investors by creating a  
    ↪ snapshot of the token balance by using ERC20Snapshot in SToken  
366:    _snapshotId = _snapshot();
```

This records who is holding sTokens at this point in time. If the borrower makes a payment and the pool turns back to `Active`, later the locked funds will be available to claim for the sToken holders at that snapshot:

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/DefaultStateManager.sol#L500-L505>

```
File: DefaultStateManager.sol
```

```
500:    /// The claimable amount for the given seller is proportional to the  
    ↪ seller's share of the total supply at the snapshot  
501:    /// claimable amount = (seller's snapshot balance / total supply at  
    ↪ snapshot) * locked capital amount  
502:    _claimableUnlockedCapital =  
503:    (_poolSToken.balanceOfAt(_seller, _snapshotId) *
```



```
504:         lockedCapital.amount) /  
505:         _poolSToken.totalSupplyAt(_snapshotId);
```

From docs:

If sellers wish to redeem their capital and interest before the lockup period, they might be able to find a buyer of their sToken in a secondary market like Uniswap. Traders in the exchanges can long/short sTokens based on their opinion about the risk exposure associated with sTokens. Since an sToken is a fungible ERC20 token, it is fairly easy to bootstrap the secondary markets for protection sellers.

If there is a uniswap (or similar) pool for this sToken, an attacker could potentially, using a flash loan, trigger the switch to Late and since they will be the ones holding the sTokens at the point of locking they will be the ones that can claim the funds at a potential unlock.

## Impact

An attacker can, using a flash loan from a secondary market like uniswap, steal a LPs possible share of unlocked tokens. Only paying taking the risk of the flash loan fee.

## Code Snippet

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L357-L366>

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/DefaultStateManager.sol#L119>

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/DefaultStateManager.sol#L137>

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/DefaultStateManager.sol#L503>

## Tool used

Manual Review

## Recommendation

I recommend you make `assessState` only callable by a trusted user. This would remove the attack vector, since you must hold the tokens over a transaction. It would still be possible to use the [withdraw bug](#), but if that is fixed this would remove the possibility to "flash-lock".



## Discussion

**vnadoda**

@clems4ev3r PR to fix this issue:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/69>

**clems4ev3r**

Fix looks good





## Issue M-7: Growing of totalSupply after successive lock/unlockCapital can freeze protection pools by uint overflow

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/118>

### Found by

clems4ever

### Summary

In a protection pool, after enough cycles of locking capital/depositing, totalSupply can grow to overflow uint256.

### Vulnerability Detail

In `convertToSToken`: <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L589-L606>

`_getExchangeRate()` can become arbitrarily small after a funds locking, since locked funds are subtracted from `totalSTokenUnderlying`; This means that new depositors can get a lot more shares than depositors from before funds locking. This behavior is correct, because otherwise previous depositors would have an oversized share of the new capital. However this has the negative effect of growing `totalSupply` exponentially, eventually reaching `type(uint).max` and overflowing (reverting every new deposit).

### Impact

Protocol can come to a halt if totalSupply reaches `type(uint).max`.

### Code Snippet

### Tool used

Manual Review

### Recommendation

Design the token in a way that it can be rebased regularly.



## Discussion

**vnadoda**

@clems4ev3r Technically it is possible but I don't think this can happen in practice.  
Cc @taisukemino

**clems4ev3r**

@vnadoda actually the risk here is to have `_getExchangeRate() == 0` after a few lock events. If the protection pool contains 1M USDC ( $10^{12}$ ), and a locking event leaves a dust amount in the pool (let's say 1 wei), next deposits for 1M USDC will multiply `totalSupply` by  $10^{12}$ . This means that after a few such events, and for a reasonable amount of underlying in the pool `_getExchangeRate() == 0` and all deposits to the pool are blocked.

Agreed that was not clearly stated in the original report. And it technically should not overflow uint.

**vnadoda**

@clems4ev3r the scenario you described is same as #117, right?

**vnadoda**

@clems4ev3r can we close this as a duplicate of #117?

**clems4ev3r**

@vnadoda not exactly the same since this will happen if some funds stay in the contract after locking. Each time a lock happens, depositing back capital will multiply `totalSupply` by a factor proportional to the locking, eventually forcing `_getExchangeRate()` to zero and blocking deposits for the `ProtectionPool`

**vnadoda**

@clems4ev3r let's discuss this on the call

**vnadoda**

@hrishibhat we are planning to fix this

**vnadoda**

@clems4ev3r @hrishibhat there is no code change for this issue. Please see my comment: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/117#issuecomment-1485956386>

**jacksanford1**

No code change planned, labeling as Acknowledged by protocol team



## Issue M-8: Freezing of the protocol when totalSTokenUnderlying is zero but totalSupply is non-zero

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/117>

### Found by

chaduke, mert\_eren, Kumpa, Web3SecurityDAO, clems4ever, jprod15, Ruhum, Bauer

### Summary

In some cases the protocol can contain zero funds while having a non zero totalSupply of STokens. In that case the protocol will not be able to accept any new deposits and any new protection buys, thus coming to a halt, unless all STokens are burned by their respective holders.

### Vulnerability Detail

In the case lockCapital has to lock all available capital:

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L415-L419>

totalSTokenUnderlying becomes zero, but totalSupply is still non-zero since no SToken have been burned. Which means that new deposits will revert because `_getExchangeRate()` is zero: <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L602-L605>

And `convertToSToken` tries to divide by `_getExchangeRate()`; <https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L602-L605>

Also all new protection buying attempts will revert because `_leverageRatio` is zero, and thus under `leverageRatioFloor`.

### Impact

The protocol comes to a halt, unless every SToken holder burn their shares by calling `withdraw` after enough cycles have passed, returning to the case `totalSupply == 0`.

### Code Snippet

### Tool used

Manual Review



## Recommendation

Keep a minimum amount of totalSTokenUnderlying in the contract in any case (can be 1e6).

## Discussion

**vnadoda**

@clems4ev3r we plan to fix this

**vnadoda**

@clems4ev3r As we have discussed, keeping the dust amount won't help with the situation when totalSTokenUnderlying is zero or tends to zero.

**We have decided that for v1, we have to make a protection pool non-operational and deploy a new protection pool, if this situation arises.**

A non-operational protection pool means nobody can buy/renew protections or deposit into the pool.

I have verified that when totalSTokenUnderlying is zero or tends to zero, because of the leverage ratio check nobody will be able to buy/renew protections plus the deposit fails because of the exchange rate being 0.

**This means, there is no code change required for this issue.**

@hrishibhat @clems4ev3r Let me know if you have any questions/concerns.

We will implement a "liquidation" process in the upcoming version to wind down the dead pool.

**jacksanford1**

No code change planned, labeling as Acknowledged by protocol team



## Issue M-9: Some protection buyers might not be able to renew their protections due to delayed expiration processing.

Source: <https://github.com/sherlock-audit/2023-02-carapace-judging/issues/27>

### Found by

chaduke

### Summary

Some protection buyers will never be able to renew their protection due to delayed expiration processing.

### Vulnerability Detail

We show below how some buyers will not be able to renew their protection due to delayed expiration process caused by the the wrong implementation of `verifyAndAccruePremium()`. Due to the bug, they might miss the deadline and grace period for renewal.

- 1) First the `verifyBuyerCanRenewProtection()` function checks whether it is too late to renew the protection (before the grace period expires). In addition, `verifyBuyerCanRenewProtection()` also checks whether there exists an expired protection with the same lending pool and position token ID at `protectionBuyerAccounts[msg.sender].expiredProtectionIndexByLendingPool[_protectionPurchaseParams.lendingPoolAddress][_protectionPurchaseParams.nftLpTokenId]` in L371. If such an existing expired protection is not there, renewal will be rejected.

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/libraries/ProtectionPoolHelper.sol#L360-L399>

- 2) In order for the expired protection to be stored in `protectionBuyerAccounts[msg.sender].expiredProtectionIndexByLendingPool[_protectionPurchaseParams.lendingPoolAddress][_protectionPurchaseParams.nftLpTokenId]`, the `expireProtection()` must be called at L1004 of function `_accruePremiumAndExpireProtections()`.

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L963-L1021>

- 3) the `expireProtection()` function stores such expired protection at L311-315:



<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/libraries/ProtectionPoolHelper.sol#L293-L321>

- 4) However, before `expireProtection()` can be called, function `verifyAndAccruePremium()` needs to be called first to decide whether a protection has expired or not (L990).

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/core/pool/ProtectionPool.sol#L963-L1021>

- 5) However, when there is no payment for a while, for example, when the last payment is made before a protection P starts (`_latestPaymentTimestamp < _startTimestamp`), P will not be considered as expired see L215-220 of `verifyAndAccruePremium()` below:

<https://github.com/sherlock-audit/2023-02-carapace/blob/main/contracts/libraries/ProtectionPoolHelper.sol#L201-L284>

- 6) Therefore, if there is no payment for a long time, then `verifyAndAccruePremium()` will always consider a protection P has not expired. `expireProtection()` will never process it. So the actually expired protection will not be stored in `protectionBuyerAccounts[msg.sender].expiredProtectionIndexByLendingPool[_protectionPurchaseParams.lendingPoolAddress][_protectionPurchaseParams.nftLpTokenId]`. The buyer for P will not be able to renew P because `verifyBuyerCanRenewProtection()` will fail to find an existing expired protection P. If there is no payment for a long time, then the buyer for P might miss the deadline and grace period and will never be able to renew P anymore.

## Impact

Some protection buyers might never be able to renew their protections due to delayed expiration processing as a result of a bug of `verifyAndAccruePremium()`.

`getActiveProtections()` might return some protections that are supposed to have expired, but not processed due to the above bug.

## Code Snippet

See above

## Tool used

VSCode

Manual Review



## Recommendation

We revise `verifyAndAccruePremium()` so that it will process and return the right value when a protection expires.

```
function verifyAndAccruePremium(
    ProtectionPoolInfo storage poolInfo,
    ProtectionInfo storage protectionInfo,
    uint256 _lastPremiumAccrualTimestamp,
    uint256 _latestPaymentTimestamp
)
    external
    view
    returns (uint256 _accruedPremiumInUnderlying, bool _protectionExpired)
{
    uint256 _startTimestamp = protectionInfo.startTimestamp;

+   uint256 _expirationTimestamp = protectionInfo.startTimestamp +
+       protectionInfo.purchaseParams.protectionDurationInSeconds;
+   _protectionExpired = block.timestamp > _expirationTimestamp;

    /// This means no payment has been made after the protection is bought or
    ↪ protection starts in the future.
    /// so no premium needs to be accrued.
-   if (
-       _latestPaymentTimestamp < _startTimestamp ||
-       _startTimestamp > block.timestamp
-   ) {
+   if (!_protectionExpired //
    ↪ @audit: only if it has not expired
+       (_latestPaymentTimestamp < _startTimestamp ||
+       _startTimestamp > block.timestamp)
+   ) {

        return (0, false);
    }

    /// Calculate the protection expiration timestamp and
    /// Check if the protection is expired or not.
-   uint256 _expirationTimestamp = protectionInfo.startTimestamp +
-       protectionInfo.purchaseParams.protectionDurationInSeconds;
-   _protectionExpired = block.timestamp > _expirationTimestamp;

    /// Only accrue premium if the protection is expired
    /// or latest payment is made after the protection start & last premium
    ↪ accrual
    if (
```



```

        _protectionExpired ||
        (_latestPaymentTimestamp > _startTimestamp &&
         _latestPaymentTimestamp > _lastPremiumAccrualTimestamp)
    ) {
        /**
         * <-Protection Bought(second: 0) --- last accrual ---
        ↪ now(latestPaymentTimestamp) --- Expiration->
         * The time line starts when protection is bought and ends when protection
        ↪ is expired.
         * secondsUntilLastPremiumAccrual is the second elapsed since the last
        ↪ accrual timestamp.
         * secondsUntilLatestPayment is the second elapsed until latest payment is
        ↪ made.
         */

        // When premium is accrued for the first time, the
        ↪ _secondsUntilLastPremiumAccrual is 0.
        uint256 _secondsUntilLastPremiumAccrual;
        if (_lastPremiumAccrualTimestamp > _startTimestamp) {
            _secondsUntilLastPremiumAccrual =
                _lastPremiumAccrualTimestamp -
                _startTimestamp;
        }

        /// if loan protection is expired, then accrue premium till expiration and
        ↪ mark it for removal
        uint256 _secondsUntilLatestPayment;
        if (_protectionExpired) {
            _secondsUntilLatestPayment = _expirationTimestamp - _startTimestamp;
            console.log(
                "Protection expired for amt: %s",
                protectionInfo.purchaseParams.protectionAmount
            );
        } else {
            _secondsUntilLatestPayment = _latestPaymentTimestamp - _startTimestamp;
        }

        /// Calculate the accrued premium amount scaled to 18 decimals
        uint256 _accruedPremiumIn18Decimals = AccruedPremiumCalculator
            .calculateAccruedPremium(
                _secondsUntilLastPremiumAccrual,
                _secondsUntilLatestPayment,
                protectionInfo.K,
                protectionInfo.lambda
            );

        console.log(
            "accruedPremium from second %s to %s: ",

```





```
        _secondsUntilLastPremiumAccrual,  
        _secondsUntilLatestPayment,  
        _accruedPremiumIn18Decimals  
    );  
  
    /// Scale the premium amount to underlying decimals  
    _accruedPremiumInUnderlying = scale18DecimalsAmtToUnderlyingDecimals(  
        _accruedPremiumIn18Decimals,  
        poolInfo.underlyingToken.decimals()  
    );  
}  
}
```

## Discussion

**vnadoda**

@clems4ev3r @hrishibhat This will be fixed with daily premium accrual change for #294

**vnadoda**

@clems4ev3r Fix for this issue is in PR:

<https://github.com/carapace-finance/credit-default-swaps-contracts/pull/57>

**clems4ev3r**

Fix looks good

