Final Report
Chinese Version
期終報告書
中文版

秘書處專用
申請編號：_ _ _ _ _ _ _

漁業持續發展基金
Sustainable Fisheries Development Fund
期終報告書
Final Report

請填妥這份期終報告書，並於項目完成後的四個月內送交漁業持續發展基金秘書處。請注意，這份報告書將會上載至漁護署網頁供公眾查閱。

項目名稱：改善香港的魚類健康和生產 (SFDF – 0031)
申請機構：香港城市大學
批准日期：2018 年 9 月 3 日
資助款額：HK$4,940,069.00
報告期間：2019 年 9 月 1 日至 2020 年 12 月 31 日

注意

凡故意在本報告書中作失實陳述或漏報資料，有關項目可被中止發放資助款項，而受資助者被發現有虛報資料，亦可遭檢控。受資助者須注意，以欺詐手段取得金錢利益，屬刑事罪行。

聲明

本人證實所夾附的期終報告書和經審計帳目，以及所提交的額外資料和證明文件均正確無誤，所購買的物料(包括資產)和獲取的服務，是本項目內的活動所必要的，而且價格公道合理。

[redacted]

簽署並機構蓋印
Signature & Co. Chop

機構負責人姓名：
Project-in-charge
Prof Sophie Natasha ST-HILARIRE

香港身分證號碼：
HKID No.: [redacted]

日期：
Date: April 23, 2021

1. 項目時間表 Project Timeline

開始日期 Project Start Date		完成日期 Project End Date	
原定 *(根據協議所示)* Planned	實際 Actual	原定 *(根據協議所示)Planned*	實際 Actual
2018 年 9 月 1 日	2018 年 9 月 1 日	2020 年 8 月 31 日	2020 年 12 月 31 日

2. 項目目的撮要 Project objectives summary

- 辨識本港水產養殖生產的主要健康限制
- 為漁護署的魚類健康檢查計劃而提供的擴增獸醫外勤服務
- 設立提供水生動物用獸藥產品的藥房
- 調查本港水產養殖業的寄生體及細菌感染問題的治療選擇
- 為生產者和魚類衛生專業人員（包括獸醫）以干預策略去制定具體的最佳實踐指導方針
- 增加本港水生動物獸醫的能力

3. 項目目的和/或範圍的更改 *(如有，請註明有何更改以及所持理由)*
Any Change of Project objectives / scope (If yes, please specify the changes and justifications)

沒有更改

4. 報告期間的項目推行撮要
(請簡述主要活動，並按適當情況列明日期、地點及受惠人數)
Project Summary/ Progress during the reporting period
(Please briefly describe the major activities, and list the date(s), venue(s) and the number of beneficiaries from the activities)

請參閱附錄 A 及 B

5. 參加者估計數目與實際數目的比較
Comparison of estimated number of partipants with actual number

日期 Date	地點 Venue	活動 Activities	預計受惠人數 Estimated number of	實際受惠人數 Actual number of	漁業界受惠人數 Number of beneficiaries

			beneficiaries	beneficiaries	in the Fishery field
2018 年 9 月至 2020 年 12 月 30 日	本港漁場	獸醫漁場探訪	60	67	67
研究					
2020 年 3 月至 5 月	本港漁場	甲氨基阿維菌素苯甲酸鹽 (Emambectin benzoate)試驗	4	5	100+名咸水漁農
2019 年 12 月	本港漁場	甲苯咪唑 (Mebendozole) 試驗	3	1	治療失敗，因此終止
2020 年 3 月至 9 月	本港淡水漁場	烏頭魚夏季水質項目	2	2	50+個潛在的本港淡水漁場
外展					
2018 年 10 月	漁農及研究人員	納米氣泡技術研討會(城大)	12	12	未明
2019 年 6 月 5 日	本港漁農	水產養殖的抗生素使用(屏山漁農協會大樓)	20	16	16 名漁農
2019 年 6 月 5 日	本港獸醫	基本的魚類健康知識(城大)	30	50	50 名獸醫
2019 年 10 月 22 日	魚類健康項目人員	水質研究(由於城大的政治抗爭，此討論在網上 Zoom 進行)	30	5	5 名魚類健康項目人員
2020 年 12 月 3 日	本港獸醫	為獸醫提供的水質研究(香港青年協會領袖學院)	30	~31	30 名獸醫
2020 年 12 月 17 日	本港漁農	治療海蝨(sea lice) (網上)	30	~34	30 名漁農

6. 項目的成效評估（根據申請計劃的成效指標）

Project effectiveness evaluation (according to the effectiveness indicators of the application form)

請參閱附錄 K

7. 項目延期（與原定時間表比較，並須交待原因）
Project Delay (Compared to the planned schedule and please provide justification.)

由於城大的政治抗爭和 2019 新型冠狀病毒疫情影響，我們的項目進度受到延遲，但除了一個持續專業進修(CPD) 課程未能推行之外，其餘所有服務和外展目標都均能完成。為配合 2019 新型冠狀病毒在家工作政策，我們的實地考察變得困難，以致我們的實驗研究數量未如預期。故此，我們退還了與此範疇相關的大量資金給漁護署。

8. 在報告期間所遇的問題（如有）
Problems/ difficulties encountered during the reporting period (if any)

受到 2019 新型冠狀病毒的限制，我們在探訪漁場去進行研究時，遇到了問題。我們只能提供緊急服務。我們有採取額外的預防措施，如穿著個人防護裝備。

9. 為解決問題所採取的補救措施及這些措施的成效（如有）
Remedial measures taken to solve the abovementioned problems and the effectiveness (if any)

我們去漁場時增加了個人防護裝備，並根據 2019 新型冠狀病毒規定，將團隊人數減少至 3 人以下。

10. 列出項目的出品（報告書、唯讀光碟等）、已製備的宣傳物料或印刷品（如有）
（請註明種類和數目，並各提供兩個副本）
Project productions (report, CD-ROM,etc), promotional materials or printed materials (if any)
(Please specify the type(s) and number and provide two copies of each)

用甲氨基阿維菌素苯甲酸鹽(Emambectin benzoate)治療海蝨(sea lice)的原稿

11. 財務報告(*請根據協議內訂明另外提供經審計賬目，可參考夾附的文件清單及樣本*)

Financial Report *(Please provide financial statement/audited accounts per stated in the agreement. Refer to the list of documents and specimen enclosed)*

a) 整體狀況

截至 2019 年 9 月 1 日 的開始結餘： 742,546.67 元

*加上*報告期間的收入： 由 2019 年 9 月 1 日 至 2020 年 12 月 31 日

共 3,149,733.57 元

(金額與「收入分項數字詳情」的總和一致)

*減去*報告期間的支出： 2,792,957.29 元

(金額與「收入分項數字詳情」的總和一致)

截至 2020 年 12 月 30 日 的結餘： 1,099,322.95 元

b) 收入分項數字詳情（包括項目利息）Details of income (including interest)

細項 Transaction items	用途 Use	金額（港元） Amount
第二期撥款		900,000.00
第三期撥款		1,300,000.00
第四期撥款		925,000.00
利息收入		24,733.57
	總計	3,149,733.57

c) 支出分項數字詳情 Details of expenses

細項 Transaction items *(請根據資助協議的「獲批項目」填寫)*	批准 預算 Budget *(請根據資助協議的「獲批項目開支」填寫。如有獲批的預算調撥，則填寫經調整後的最新金額)*	實際 開支 Expenses *(請保留所有收據正本)*	預計 開支 Est. expenses *(預計下一報告期內開支)*	數量 Quantity *(請根據資助協議的「獲批項目」填寫)*	申請者的單據／收條編號 Invoice/ Receipt no.
G1. Personal protective equipment	31,776.00	12,122.10		2 batches	441089 OHRP 191127035 R1 PH 200330005 R1 OHRP 200810048 R1 SI3028604 PH 201028020 R1 PH 201103014 R1 PH 201103015 R1 PH 201123092 R1 PH 201123093 R1 PH 201124015 R1 PH 201217014 R1 PH 201224015 R1 5121144277
G2. PM/histo	160,657.00	70,290.00		400 times	AN19381TK 19000957 19000955 19000958 19000960 19000956 19001302 19001301 19001070 19001071 19001184 19001186 20000223 20000224 20000236 20000470 20000471 20000597 20000846 20000847 20000848 20000863 20000864

					20001260 20001261 20001262 20001127 20001128 20001403 20001404 20001405 20001406
G3. PM/PCR	190,070.00	83,521.78		400 times	IN1910034 IN1910029 MFI1910037 20225867 5121131316 IN20-007414 IN20-007326 IN20-007742 S10/10122755 IN2004815 95046684 95046848 IN20-008615 20071506 20231148 20071506TT 22200-0002872 22200-0002875 S10/10125196 20242347 20242806 SITIVCTU2012312 201200127 201200129 201200135 201200142 201200163 PO617969 PO617969TT 9881LT
G4. PM/ bacteriology culture	120,005.00	7,200.00		400 times	19000958 19001070 19001071 19001184 19001186 20000224 20000236 20000471 20000481 20000597 9181LP
G5. Sensitivity analysis/ MIC analysis	93,470.00	23,030.00		400 times	19000960 19000956 19000957 19001070 19001184

					20000223 20000236 20000470 20000471 20000481 20000864 20001260 20001262 20001127 20001128 20001403 20001404 20001405 20001406
G6. Water quality tests	404,431.00	281,229.49		80 times	SI202000023 112A71113 112A71543 112A71738 112A72066 112A72161 SI202000593 112A73206 112A73242 112A71841 112A72258 112A72534 112A72551 112A72627 112A72857 112A72858 112A73558 112A73759 112A74070 112A71420 112A74407 112A74537 112A74855 112A74998 112A75246 112A75410 SI202000813 112A76045 137327 00137327TT 112A77321 112A77432 11669 112A76191 112A76476 112A76612 112A76995 112A77019 112A77102 SI200921001 SI202000996

					112A73995 112A77842 112A77843 112A77953 SI202001261 112A75583 112A76334 112A77400 112A77407
G7. Parasitology tests	51,350.00	26,192.98		400 times	4145046126
G8. Miscellaneous expenses with pharmacy	161,965.41	16,162.73		2 times	441089 441089 PH 191111024 R1 PH 191111026 R1 PH 191111028 R1 OHRP 191204011 R1 9208148123 PH 191231039 R1 PH 200414021 R1 PH 200414022 R1 I20200503 PH 200923031 R1 OHRP 210113020 R1
G9. HPLC analysis of tissues	158,520.00	83,000.00		240 times	DN-CTS-200082 DN-CTS-200081 DN-CTS-200108 DN-CTS-200155 DN-CTS-200163 DN-CTS-200217 DN-CTS-200218 DN-CTS-200237 DN-CTS-200262 DN-CTS-200288 DN-CTS-200317 DN-CTS-200332 DN-CTS-200342 DN-CTS-200371 DN-CTS-200442 DN-CTS-200426 DN-CTS-200427 DN-CTS-200539
G10. Monthly use of tanks and care of fish	121,482.00	11,616.46		12 months	PH 191107024 R1 MFI1910037 PH 200317031 R1 PH 200317032 R1 PH 200317034 R1 PH 200327012 R1
G11. Pharmaceuticals	120,011.90	20,138.10		2 batches	I20200503 I20200503
G12. Cost of fish	126,700.00	17,000.00		600 fishes	20190527/CITYU 20190603/CITYU PH 191010015 R1

					PH 200514044 R1 PH 200514045 R1 PH 200602020 R1 PH 200624021 R1
G13. 3 continuing education sessions for veterinarians	46,555.93	7,413.24		60 people	PH230420 PH230420A PH230420ATT 1343 1343TT
G14. 2 workshops for industry	61,769.10	0.00		80 people	
G15. Printing materials	31,291.10	1,239.10		2 times	1179102 PH 191111023 R1 851010 OHRP 200327013 R1
G16. Consultant travel cost	20,070.00	0.00		5 times	
G17. Consultant subsistence cost	0.00	0.00		20 days	
G18. Consumables (slides, stains, etc)	98,291.90	52,491.16		2 years	4861KJG PH 190926015 R1 PH 190926021 R1 PH 190919034 R1 PH 190919033 R1 4554KLGPE PH 191017018 R1 PH 191204014 R1 PH 191231044 R1 PH 191231046 R1 PH 200115046 R1 PH 200327009 R1 OP/I965609 SI202000377 SI202000377 SI202000377 PH 200422006 R1 PH 200514047 R1 7340LD 7636LE PH 200601007 R1 PH 200602018 R1 IN20-007998 PH 200706031 R1 PH 200706033 R1 PH 200804016 R1 PH 200812007 R1 PH 200818008 R1 PH 200902026 R1 PH 200928053 R1 PH 201016009 R1 PH 201028019 R1 PH 201201069 R1 PH 201217017 R1

					9208177567 9208177568 20243520 20210027915 9202LTP2 IN20-012720 206271
G19. Car rental (including insurance)	196,469.38	72,909.40		140 times	PH 191003014 R1 PH 191205040 R1 PH 191231042 R1 PH 200514042 R1
G20. Petrol	51,139.47	35,706.47		140 times	PH 190911012 R1 PH 190926020 R1 PH 190926019 R1 PH 190926018 R1 PH 190926017 R1 PH 191010014 R1 PH 191010013 R1 PH 191010012 R1 PH 191104019 R1 PH 191107022 R1 PH 191107021 R1 H000659098 H000671034 H000677078 PH 191204016 R1 PH 191205041 R1 PH 191231038 R1 PH 191231037 R1 PH 191231036 R1 PH 200115042 R1 PH 200115044 R1 PH 200115043 R1 H000689098 PH 200317033 R1 PH 200325008 R1 PH 200325009 R1 PH 200325010 R1 PH 200327011 R1 PH 200414023 R1 PH 200414024 R1 H000716087 PH 200511014 R1 PH 200508023 R1 H000726518 H000731491 PH 200601009 R1 PH 200602016 R1 PH 200514038 R1 PH 200514039 R1 PH 200514040 R1 PH 200514041 R1 PH 200514049 R1 PH 200624018 R1 PH 200624019 R1

					PH 200624020 R1 H000751545 PH 200706028 R1 PH 200706029 R1 PH 200706030 R1 PH 200804013 R1 PH 200804014 R1 PH 200804015 R1 PH 200812008 R1 PH 200812009 R1 H000760854 PH 200818003 R1 PH 200818004 R1 PH 200818005 R1 PH 200818006 R1 PH 200902025 R1 PH 200902028 R1 PH 200902029 R1 PH 200902030 R1 PH 200928051 R1 PH 200928052 R1 PH 200929047 R1 PH 201012035 R1 PH 201012036 R1 H000769649 PH 201028022 R1 H000778386 H000778386 H000791737 H000778386 PH 201201067 R1 PH 201201068 R1 PH 201217016 R1
G21. Boat transportation	71,700.00	29,937.00		30 times	PH 190919032 R1 PH 191107023 R1 PH 191204012 R1 PH 191204013 R1 PH 191204017 R1 PH 191204015 R1 PH 191231045 R1 PH 191231043 R1 PH 191231041 R1 PH 191231040 R1 PH 200115045 R1 PH 200325007 R1 PH 200327010 R1 PH 200422005 R1 PH 200514043 R1 PH 200514046 R1 PH 200602017 R1 PH 200602019 R1 PH 200706032 R1 PH 200818007 R1 PH 201201066 R1 PH 201217015 R1

M1. 2 veterinarians (part-time)	1,763,900.58	1,172,597.28		24 months	M1-01-01 M1-01-02 M1-01-03 M1-01-04 M1-01-05 M1-01-06 M1-01-07 M1-01-08 M1-01-09 M1-01-10 M1-01-11 M1-01-12 M1-01-13 M1-01-14 M1-01-15 M1-01-16 M1-02-01 M1-02-02 M1-02-03 M1-02-04 M1-03-01 M1-03-02 M1-03-03 M1-03-04 M1-03-05 M1-03-06 M1-03-07 M1-03-08 M1-03-09 M1-03-10
M2. 1 technician for veterinary (full-time)	376,103.23	340,200.00		24 months	M2-01-01 M2-01-02 M2-01-03 M2-01-04 M2-01-05 M2-01-06 M2-01-07 M2-01-08 M2-01-09 M2-01-10 M2-01-11 M2-01-12 M2-01-13 M2-01-14 M2-01-15 M2-01-16
M3. 1 technician for research (part-time)	330,540.00	329,175.00		24 months	M3-01-01 M3-01-02 M3-01-03 M3-01-04 M3-01-05 M3-01-06 M3-01-07 M3-01-08 M3-01-09

					M3-01-10 M3-01-11 M3-01-12 M3-01-13 M3-01-14 M3-01-15 M3-01-16
M4. 1 administrative assistant for outreach (part-time)	95,800.00	85,785.00		5 times	M4-01-01 M4-01-02 M4-01-03 M4-01-04
G22. Expert consultant for outreach (honorarium)	0.00	0.00		5 times	
G23. External audit	56,000.00	14,000.00		2 years	47002810367

12. 申請發放最後一筆資助款項的金額（如有）
Amount requested for next installment (if any)

沒有

13. 須歸還政府的餘款數目（如有）
The amount of unspent balance to be returned to the government (if any)

$ 1,099,322.95

＜完 END＞

註 1：實際開支中[$0]已於報告期內支付。餘下[$5000]元按權責發生制原則計提，屬本報告期的應付未付費用，並於下一份報告書內繳付。

文件清單

		是	否 *(請於備註提供原因)*	有關文件/備註
1	已根據資助協議要求，另外提交財務報表／經審計賬目。 *(財務報表包括財務狀況表(資產負債表)及收入支出表；經審計賬目包括核數師報告（包括證明受資助者按照批撥條件使用資助額的聲明）、財務狀況表(資產負債表)、收支表、現金流動表及其他附註解釋資料。) 收支表須清楚列明各收入及支出細項(參考協議 Schedule II 內的獲批預算)，有關收入及支出細項應為經審計帳目內的一部分，受資助者有責任通知核數師有關要求。)*	☑	☐	

2	確認另外提交的財務報表／經審計賬目與進度／年度報告書的財務資料一致。 如資料不一致，請另外說明。	☑	☐	
3	就「項目收入」，除政府資助金額外，確認已提交其他收入的證明及內容。	☑	☐	
4	除利息收入、政府資助及已於申請書明的預計收入外，報告期没有其收入。 如有非申請書聲明的其他收入，請說明相關性質及提供證明。	☑	☐	
5	就員工開支，確認已提交「薪金簽收單」及各員工的對應「強積金供款確認書」。	☑	☐	
6	確認項目所有員工於項目期間只進行項目的相關工作。	☑	☐	
7	如「獲批項目開支」與資助協議內的原金額不同，確認所有經調整的「獲批項目開支」已預先向秘書處申請並獲得批准。	☑	☐	

附錄

附錄 A 城大水生動物獸醫服務檢討

附錄 B 成果表

附錄 C 個案表列 (只提供英文版本)

附錄 D 客戶名單 (只提供英文版本)

附錄 E 客戶感謝來信 (只提供英文版本)

附錄 F 甲氨基阿維菌素苯甲酸鹽(Emambectin benzoate) 原稿 (只提供英文版本)

附錄 G 抗菌素耐藥性(AMR)表 (只提供英文版本)

附錄 H 烏頭魚夏季調查 (只提供英文版本)

附錄 I 外展活動 (只提供英文版本)

附錄 J 年度香港魚類健康問題內部報告 (只提供英文版本)

附錄 K 預計成果及項目影響

附錄 L 香港海魚疾病調查 (只提供英文版本)

附錄 A

城大水生動物獸醫服務檢討

附錄 A

2018/2019/2020 城市大學非住院水產獸醫門診服務檢討

背景:

城市大學非住院水產獸醫門診服務(此服務)於2018 年10 月開始運作，此服務迎合本地水產養殖魚農及相關行業的需要。於2020年12月此服務聘用兩名兼職獸醫、一名全職技術主任及一名兼職技術主任以運作，並由兩名城市大學賽馬會教職員工輔助回應求助個案、針對於實地視察時辨識到的健康問題進行究研計劃以及管理整個項目計劃。附錄B 表列建議活動以及我們在過去的成果。以下是這項計劃的概述。僅於2019年11月抗議期間，以及為配合政府實施COVID-19疫情控制，我們開始減少服務，僅為緊急個案進行實地視察。

<u>建立</u>:

- o 聘任名兩來自香港兼職獸醫
- o 聘任一名全職技術主任及一名兼職技術主任
- o 建立接收及跟進個案的服務
    - 專用電話熱線
    - 專用軟件系統
    - 基本設備
    - 專用車輛
    - 與城大動物醫療檢驗中心的合作計劃
    - 設於城大動物醫療中心的藥房

<u>服務</u>:

在 2.5 年運作中，我們的獸醫服務有：

- 回應了來自67位客戶共161件案例 (2018年有21件案例、2019年有62件案例、2020年有78件案例)，及408次現場訪問（請參閱載於附錄C 的個案詳情，及載於附錄D 的客戶(受惠人)及聯絡資料名單）。我們亦提供了附錄C 的Excel 試算表電子檔案，在這些個案中有34 個個案需要處方藥物治療。此外，我們提供了一封客戶來信，是關於我們首年提供服務的成果（請參閱附錄E）。
    - o 我們的漁場實地視察一般包括：水質評估、提取魚類樣本供診斷檢查，並按個案所需包括剖驗魚屍、濕裱、組織抹片、細菌學/敏感度、以及組織學分析，而我們將樣本送交漁護署作病毒學測試。
    - o 訖今已辨識到的疾病和病原體以及治療包括：
        - 細菌：創傷弧菌屬*(Vibrio spp.)*、發光桿菌屬*(Photobacterium spp.)*、分支桿菌屬*(Mycobacterium spp.)*、產氣單胞菌屬*(Aeromonas spp.)*、海豚鏈球菌*(Streptococcus iniae)*、金黃桿菌屬(*Chryseobacterium spp)* 、愛德華菌

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屬(*Edwardsiella spp*)、腸桿菌屬(*Enterobacter spp*)、鄰單胞菌屬(*Plesiomonas spp*)、葡萄球菌屬(*Staphylococcus spp*)。

- 寄生蟲：海水白點蟲(*Crytocaryon irritant*)、單殖類吸蟲綱(*Monogeneans*)、盾狀纖毛蟲(*scuticociliates*)、海蝨(*sea lice*)、血居吸蟲屬(*Sanguinicola spp.*)、多毛魚虱(*Ichthyophthirius multifiliis*)、捲毛蟲屬(*Trichodina*)、卵旋蟲屬(*Oodinium*)、卵圓鞭毛蟲屬(*Amyloodinium*)、斜管蟲屬(*Chilodonella*)、布魯克利纖毛蟲屬(*Brooklynella*)。
- 病毒性：虹彩病毒 (傳染性脾臟與腎臟壞死病毒 及 嘉納虹彩病毒) (Iridovirus (ISKNV and RSIV))、病毒性神經壞死病毒 (Viral nervous necrosis (VNN))。
- 水質問題：於夏季出現在土塘的溶解氧和氨(Ammonia)含量高，以及酸鹼度波動問題；出現在循環系統的氨(Ammonia)、亞硝酸鹽(Nitrite)及硝酸鹽(Nitrate)問題。

- 藥劑
  - 我們已發展出一個能供應魚類藥劑產品的功能性藥房。我們亦已建議更改計劃預算來資助魚農一半的藥物開支，以減少他們非法購買抗生素(即魚農在沒有適當的醫生處方下購入藥物)，而是項建議在2019 年10 月11 日獲得漁業持續發展基秘書處批准。我們能提供的兩種抗生素現時價格為：
    - 羥四環素(OTC)每公斤26 美元(每1000 公斤的魚類需使用1.4 公斤的羥四環素，所需費用為38 美元。)
    - 氟甲磺氯黴素(Florfenicol)每公斤60 美元(每1000 公斤的魚類需使用300 克，所需費用為20 美元。)
  - 初步研究發現甲氨基阿維菌素(Emamectin Benzoate)可用於治療海蝨(sea lice)(附錄F)我們將會採購該藥，以便提供給客戶。

- 非住院獸醫門診服務的地點
  - 我們已將此服務遷往位於深水埗的丰滙。同時，我們亦能在城大動物醫療檢驗中心的解剖室中進行魚屍剖驗。

- 已知限制
  - 非住院水產獸醫門診服務能力受到外在因素影響，並於2019 年11 月到2020 年1 月開始配合學校調整在家工作政策，僅為緊急案進行實地視察服務。即使遇到這些困難，我們仍能將我們客戶服務持續增加至67 位，並且幫助魚農應對緊急魚類健康問題。

研究:

- 我們追蹤全部分離到的菌株所呈現的抗菌素耐藥性（附錄G）。
- 我們發表甲氨基阿維菌素(Emamectin)治療海蝨(sea lice)試驗（附錄F）。
- 我們已經指派一名研究生負責為魚農規劃生物安全，但因受到新冠肺炎疫情影響，目前難以進行現場拜訪。
- 我們完成夏季烏頭(Mullet)魚場水質的初步評估。
    - 結果顯示水質是主要問題因素，但在2020年夏季的水質沒有發生嚴重問題。
        - 我們有一份調查結果的簡短報告（附錄H）。
    - 將於2021年5月為養魚戶舉辦水質講習班。

外展:

- 由於本港的政治情況，我們無法於2019年秋季邀請專家演講，因此我們會為獸醫及技術主任安排了一次Skype 視像會議，以支援我們於實地視察魚場時提供水質服務(視訊會議參與者，請參閱載於附錄 I)。
- 由於 COVID-19 疫情影響，我們無法為魚農及獸醫舉辦面對面的講習班，所以於 2020 年 12 月進行線上視訊講習班(附錄 I)。
- [redacted]獸醫於 2019 年 12 月、2020 年 9 月和 10 月分別為香港浸會大學的香港有機資源中心及香港理工大學作為講習班講師(附錄 I)。

附錄 B

成果表

附錄 B

受助於漁護署漁業持續發展基金的「改善香港的魚類健康和生產」計劃的活動 2018 年 9 月至 2020 年 12 月

活動目的 (包括計劃、招聘)	完成日期	預料參與者人數	評語
僱用人員 • 獸醫 1 (兼職) • 獸醫 2 (兼職) • 技術主任 (全職) • 技術主任 (兼職)	• 2018 年 10 月 • 2019 年 2 月 • 2019 年 9 月 • 2019 年 10 月	• 4 位人士受惠於是項招聘活動。 我們其間同時訓練了另外兩位魚類健康技術員，他們分別成為了城市大學的研究生和得到城市大學的常規編制職位。這兩位學員的工作仍與魚類相關。	• 我們聘用了兩名兼職獸醫而非一名全職獸醫，因為我們未能找到願意全職工作的魚類獸醫。 • 我們聘用了全職技術主任 ([redacted]) 在此聘任之前我們為兩位人士提供了魚類健康的訓練 ([redacted]) • 我們聘用了一名由漁護署退休的技術主任([redacted]
服務： 為水產養殖客戶提供獸醫服務 • 建立魚農能接觸到並從中獲魚類健康管理的建議的獸醫學服務 • 建立存有魚類適用藥物的藥房	• 請參閱載於附錄C 的實地視察日期及個案資料 • 2019 年 3 月	• 在此報告期間，我們為67 位水產養殖客戶提供了獸醫服務建議。 • 我們的藥房現時貯存了兩種抗生素，包括羥四環素和氟甲磺氯黴素；及兩種杜蟲藥，包括甲氨基阿維菌素苯甲鹽酸及吡喹酮。我們將會資助魚農的藥費，以鼓勵魚農不再在沒有獸醫處方的情況下由內地或網上購買藥物。	• 我們高估了使用我們服務的魚農人數，但也低估了個案數量。 • 我們成為漁護署的魚類健康計劃的合作伙伴。 • 過去 6 個月，我們為魚農設立了預防性探訪。 • 我們舉辦了額外的講座給予魚農，以改善及鼓勵魚農遵守魚類健康措施。
研究項目			

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附錄 B

研究：水產動物健康評估	2020 年 4 月	• 現有 38 名客戶	• 我們在附錄C 中概括了我們調查過的個案及提供了此Excel 試算表的電子檔案。我們並在附錄 J 中概述了在過去一年我們觀察所得的常見問題。 • 我們將服務及研究計劃重點放在專注於緩解附錄J所提及到的常見問題。
研究： 評估以甲氨基阿維菌素 (emamectin benzoate (EMB))治療海魚體外寄生蟲	2021 年 2 月	• 我們已完成 EMB 的試驗並將結果於學術期刊登	• 我們成功治療在石斑魚身上海蝨。我們於 2021 年 2 月於學術期刊登 了我們的試驗結果 (附錄 F)。 • 魚農表示滿意此試驗的結果。
研究：烏頭魚夏季死亡綜合症	2020 年 4 月至 8 月	• 我們在整個夏季期間，調查了在本港泥塘養殖烏頭的水質	• 由於新冠病毒疫情影響，此項目受到輕微阻延。我們發現當時水溫對烏頭魚非常高，並發現水的溶氧量、氨氮濃度及酸鹼度一直在反覆波動 (附錄 H)。 • 雖然水質如此，但我們並未觀察到像過去報導的那樣高的魚類死亡率。反而，所有的死亡是因為管理問題或因為有暴風雨。
研究：為魚農訂立生物安全計劃	2020 年 8 月啟動	• 對 21 位海水魚農進行了有關他們對魚類管理的問卷調查	• 我們將會以研究生項目的形式來開始進行此項目。由於受新冠病毒疫情影響，我們並未能進行實地研究，此安排為一個合適的替代項目。
外展			

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附錄 B

培訓水產動物獸醫實習計劃(每年名額一位)	2020 年 12 月	• 我們已完成一位獸醫的訓練 [redacted] • 我們現正訓練另一位獸醫[redacted]) • 我們已完成兩位技術員的訓練 [redacted]	• [redacted]醫生在2019 年1 月加入我們團隊時治療魚類經驗有限，她的培訓為期 12 個月。 • [redacted]醫生由 2020 年3 月開始與我們的獸醫團隊一同工作 • [redacted]由 2018 年10 月至2019年10月與我們的獸醫團隊一同工作 • [redacted]由 2019 年10 月至2020年12月與我們的獸醫團隊一同工作
發展及教授兩個供城市大學的本科生報讀的魚類健康課程 提供獸醫實習機會(為期一星期)	1/9/18 至15/12/18； 1/1/19 至1/05/19 ； 及 02/09/2019 至 14/12/2019 ； 07/01/2020 2020 年 1 月；2020 年 5 月	• 我們已預備及教授了三個本科生，課程予共53位城市大學的獸醫學士生。 • 我們帶領了8位學生外出實習為期一星期的實習。	• 在我們的多個課程中，有一個課程關於淡水水產養殖及魚類健康、另有一個課程關於海水水產養殖及魚類健康。 • 由 2020 年1 月尾開始，我們以網上授課形式教授魚類健康課程。我們只能暫停實地考察及實驗室實用課，不過我們已改動課程以適應情況(請參閱附錄 J)。 • 由於新冠病毒疫情影響，縮短了實習生的實習時間，但我們仍然能夠帶領 8 位學生完成實習，每次帶兩位學生到魚場。
發展及舉辦了3 個有關水生動的獸醫持續進修課程 • 基本水生動物獸醫醫學 • 水質研討會(延遲)	• 2019 年6 月5 日 • 2020 年 12 月 3 日	• 約 50 位獸醫報讀了講授課程，以及 35 位參加了實驗室課節。 • 約有 25 位獸醫參加了網上水質研討會	• 我們因為本港的政治不穩定因素及新冠病毒疫情而未能舉辦第二個獸醫持續進修課程。我們講者在上年11 月時取消了行程而至今仍未能重新安排。

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舉辦了兩個關於魚類健康問題及治療選擇的研討會 • 由來自新加坡的代表 (James Chow, AquaPro) 發表納米水泡產生器 (Nanobubbler) • 謹慎使用抗生素 • 海蝨網上工作坊 • 有機農夫魚類健康工作坊 • 水質研討會﹙延後至2021年5月﹚	• 2018 年 10 月 • 2019 年 6 月 5 日 • 2020 年 12 月 17 日 • 有機資源中心：2019 年 12 月 19 日 和 2020 年 9 月 16 日 • 理工大學：2020 年 9 月 25 日 和 2020 年 10 月 2 日	• 12 位魚農及研究人員出席了我們的納米水泡產生器研討會 • 16 位魚農出席了關於抗生素的研討會 • 約15位魚農出席了海蝨網上工作坊 • 魚類健康講座由[redacted]醫生主講	• 我們原訂於2018 年10 月為魚農舉辦的會議由於嘉賓講者因政治不穩定因素取消行程而需取消，但我們安排了我們的團隊與講者進行Skype 視像會議，提供團隊有關水塘水質問題的培訓。此網上研討會令我們能夠設立水質化驗室。 • 我們原訂在3 月舉行的研討會亦延後，我們預計能在 2021 年 5 月為魚農舉辦此研討會。 • 為有機資源中心進行了 2 次演講 • 為理工大學進行了 2 次有關魚類認證計劃演講

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Appendix C

List of Cases

Appendix C. List of cases from June 2018 to December 2020.

Date	Case number	Client ID	General location	Fish species	Photos	Disease (s) diagnosed	Recommendation(s) including the usage of	Dosage	Rx number
20/6/2018	2018-12	2	Tai Po	Hybrid grouper					
20/6/2018	2018-13	#N/A	Tai Po	Hybrid grouper					
28/7/2018	2018-14	18	Sam Mun Tsai	Pompano					
28/7/2018	2018-29	18	Sam Mun Tsai	Sea bream					
28/7/2018	2018-35	18	Sam Mun Tsai	Muddy					
19/9/2018	2018-16	6	Lau Fau Shan	Grouper		H2O2 burns, Brown blood syndrome			
02/10/2018	2018-17	1	Sai Kung	Pompano		Parasitic infection - Cryptocaryon	Continue with formalin bath treatments		
5/10/2018	2018-18	2	Tai Po	Pompano		Bacterial infection - mixed vibrio sp. (not systemic)			
5/10/2018	2018-19	3	Sai Kung	Pompano		Bacterial infection - Streptococcus iniae (systemic)	Freshwater bath	20 mg/kg*10 days	RX C2018-05
9/10/2018	2018-20	3	Sai Kung	Grouper	2018-20	Wild fish has positive for photobacterium sp.	-None because fish are close to market size -Florfenicol	20 mg/kg*10 days	RX C2018-06
15/10/2018	2018-21	3	Sai Kung	Rabbit fish		Suspect bacterial infection	Florfenicol, Increase supplement vit C		
16/10/2018	2018-23	3	Sai Kung	Japanese Eels		Parasitic infection - trichodina (mild)	Improve water quality add biofilter, Provide increased water exchanged and circulation		
20/10/2018	2018-19	3	Sai Kung	Pompano		Bacterial infection - Streptococcus iniae (systemic)	Florfenicol and increased the oxygen in the water	75 mg/kg*10 days	RX C2018-10
20/10/2018	2018-36	3	Sai Kung	Grouper		Parasitic infection - Sea lice	Emamectin TRIAL ONLY		
22/10/2018	2018-19	3	Sai Kung	Pompano		Bacterial infection - Streptococcus iniae (systemic)	Florfenicol and increased the oxygen in the water	100 mg/kg*10 days	RX C2018-12
22/10/2018	2018-23	3	Sai Kung	Japanese Eels		Parasitic infection - trichodina (mild)	Improve water quality add biofilter, Provide increased water exchanged and circulation		
22/10/2018	2018-24	3	Sai Kung	Pompano (medium size)		Parasitic infection - Moderate to severe	Oxytetracycline and formalin bath	20 mg/kg*7 days	RX C2018-13
22/10/2018	2018-25	3	Sai Kung	Whitemouth croalcer		Parasitic infection - Gill clip: Moderate cryptocaryon irritans observed on primary filament.	Formalin bath and increase air		
29/10/2018	2018-26	66	Kowloon Tong	Horseshoe crabs from school					
30/10/2018	2018-24	3	Sai Kung	Pompano (medium size)		Parasitic infection - Moderate to severe	Oxytetracycline and formalin bath		
30/10/2018	2018-19	3	Sai Kung	Pompano		Bacterial infection - Streptococcus iniae (systemic)	Florfenicol and increased the oxygen in the water	20 mg/kg*7 days	RX C2018-08
19/11/2018	2018-27	4	Lamma Island	Sabah hybrid grouper			Florfenicol	20 mg/kg*7 days	RX C2018-15
29/11/2018	2018-28	5	Yim Tin Jai	Hybrid grouper	2018-28	Parasitic infection - Sea lice	Emamectin TRIAL ONLY	50 ug/kg/day*7 days	RX C2018-16
17/12/2018	2018-28	5	Yim Tin Jai	Hybrid grouper		Parasitic infection - Sea lice	Emamectin TRIAL ONLY		
17/12/2018	2018-30	3	Sai Kung	Pompano	2018-30	Mixed infection - Parasites (monogeneans) and bacteria	Oxytetracycline	100 mg/kg/day*6 days 100 mg/kg/day*7 days	RX C2018-17 RX C2018-18

17/12/2018	2018-31	3	Sai Kung	Pompano	2018-31	Moderate Trichodina, Other small worm like parasite (Moderate), Amyloodinium? And bacterial disease	Oxytetracycline		
17/12/2018	2018-32	3	Sai Kung	Pompano	2018-32	Bacteria, & moderate to heavy monogenean parasite	Oxytetracycline		
4/2/2019	2019-03	6	Lau Fau Shan	Giant Grouper		Parasitic infection - trichodina	Formalin bath		
28/2/2019	2019-04	7	Sam Mun Tsai	Grouper	2019-04	Parasitic infection - sea lice	Oxytetracycline, formalin bath	110 mg/kg/day*7 days	RX C2019-01
4/3/2019	2019-05	8	Fanling	Jewel Perch, Tilipa	2019-05	Routine visit	None		
6/3/2019	2019-06	67	Mai Po	Koi/Carp					
11/3/2019	2019-07	9	Yung Shue O	Chicken grunter	2019-07	Sudden mortality	None		
12/3/2019	2019-08	13	Yuen Long	Pearl Perch	2019-08	Routine visit	None		
2/4/2019	2019-10	6	Lau Fau Shan	Giant Grouper	2019-10	Skin ulcers			
12/4/2019	2019-11	5	Yim Tin Jai	Hybrid grouper	2019-11	Sea lice, monogeneans and bacterial infection	-Florfenicol (2020/04/17) -Suggested isolated infected fish with other fish. -Stop formalin bath because mucus on fish is reduced possibly from over treatment	15 mg/kg/day*10 days	RX C2019-06
13/4/2019	2019-12	3	Sai Kung	Pompano		Parasitic infection - Cryptocaryon	Continue and monitor formalin treatment effect		
15/4/2019	2019-13	6	Lau Fau Shan	Grouper		Bacterial infection	Monitor as fish are off feed		
7/5/2019	2019-14	3	Sai Kung	Pompano		Mixed infection - Bacterial infection, cryptocaryon			
14/5/2019	2019-15	18	Sam Mun Tsai	Pompano		General visit for nanobubbler			
22/05/2019	2019-17	20	Cheung Sha Wan	Croacker	2019-17	Bacterial infection (mixed)	Medical intervention not offered as they are to be sent to market		
27/05/2019	2019-18	22	Au Tau	Shrimp					
21/6/2019	2019-21	19	Tai Tau Chau	Hybrid grouper	2019-22	Bacterial disease	OTC prescribed	100 mg/kg/day*7 days	RX C2019-11
24/6/2019	2019-22	3	Sai Kung	White Croacker	2019-23	Environmental issue, nutritional issue	Care with transport - acclimatise properly		
24/6/2019	2019-23	3	Sai Kung	Pompano	2019-24	Parasitic issue			
27/06/2019	2019-24	10	Yim Tin Jai	Grouper		Bacterial infection and water quality issue			
10/7/2019	2019-25	11	Mai Po	Grass carp		Water quality?			
11/7/2019	2019-26	17	Mai Po	Mullet		Water quality	Increase aeration - turn on pumps (client concern - cost for electricity)		
16/7/2019	2019-27	12	Hok Tau / Fanling	Jewel Perch	2019-27	Buoyancy disorder	None - one off conidtion with perforation of swim bladder		
17/07/2019	2019-28	13	Yuen Long	Jade perch		Red spots on body			
22/7/2019	2019-29	6	Lau Fau Shan	Grouper		Bacterial infection			
23/07/2019	2019-22	3	Sai Kung	White croaker		Environmental issue, nutritional issue	Care with transport - acclimatise properly		

25/07/2019	2019-31	13	Yuen Long	Jade perch	2019-31	Suspect bacterial infection	OTC prescribed		
31/07/2019	2019-32	13	Yuen Long	Jade perch	2019-32	Water quality / bacterial issue	OTC prescribed	100 mg/kg/day*10 days	RX C2019-12
2/8/2019	2019-33	12	Hok Tau / Fanling	Tilapia	2019-33	Enviromental issue, bacterial infection (secondary)	Correct environment - lower stocking density, increase water exchange, decrease feeding		
7/8/2019	2019-32	13	Yuen Long	Jade perch	2019-32		OTC prescribed	15 mg/kg/day*10 days	RX C2019-13
8/8/2019	2019-35	13	Yuen Long	Jade perch	2019-35	Sore in the tail, white eye, parasitic	-None yet - pending culture and sensitivity results. -Reduce feeding, correct water quality issue. -Praziquantel (2020/08/09)	35 mg/kg/day*3 days	RX C2019-14
12/08/2019	2019-37	12	Hok Tau / Fanling	Tilapia/jade perch	2019-37	Water quality check up	Correct water quality issue		
13/08/2019	2019-38	12	Hok Tau / Fanling	Tilapia	2019-38	Bilateral exophthalmos - retrobulbar abscess	Monitor other fish		
19/08/2019	2019-32	13	Yuen Long	Jade perch		Suspect bacterial issue	OTC prescribed		
20/08/2019	2019-26	17	Mai Po	Mullet	2019-26	Water quality	Increase aeration - turn on pumps (client concern -		
21/08/2019	2019-39	2	Tai Po	Bat fish	2019-39	Water quality / sepsis	None yet as culture and sensitivity result were conclusive		
26/8/2019	2019-40	13	Yuen Long	Jade perch	2019-40	Water quality / bacterial	Follow up		
27/8/2019	2019-39	2	Tai Po	Batfish	2019-39	Water quality / sepsis	None yet as culture and sensitivity result were conclusive		
28/8/2019	2019-41	16	Mai Po	Mullet	2019-41	Suspect water quality issue	Non - need confirmation of water quality issue		
29/8/2019	2019-39	2	Tai Po	Bat fish	2019-39	Water quality / sepsis	-None yet as culture and sensitivity result were conclusive. -Oxytetracycline(2020/08/28)	100 mg/kg/day*10 days	RX C2019-15
04/09/2019	2019-26	17	Mai Po		2019-26	Water quality	Increase aeration - turn on pumps (client concern - cost for electricity)		
04/09/2019	2019-42	16	Mai Po	Mullet	2019-42	Water quality issue, secondary problem	Correct water quality issue		
05/09/2019	2019-43	15	Lamma Island	Cobia	2019-43	Suspect parasitic problem	None - farmer moved sea pen to water with higher current flow, and consider problem in control		
9/9/2019	2019-44	3	Sai Kung	Batfish	2019-44	Suspect water quality issue / potential viral infection	Correct water quality issue		
13/9/2019	2019-45	6	Lau Fau Shan	Grouper		High mortalities and morbidity	Correct water quality issue		
16/9/2019	2019-46	21	San Tin	Jade perch	2019-46	Mortality	Correct water quality issue		
17/9/2019	2019-46	21	San Tin	Jade perch	2019-46	Mortality	Correct water quality issue		
20/9/2019	2019-47	13	Yuen Long	Jade perch	2019-47	Mortality and red eye	Correct water quality issue		
23/9/2019	2019-48	18	Sam Mun Tsai	Batfish	2019-48	Mortality	Correct water quality issue		
24/9/2019	2019-47	13	Yuen Long	Jade perch	2019-47	Mortality and red eye	Correct water quality issue		

24/9/2019	2019-49	13	Yuen Long	Jade perch	2019-49	Parasite	Praziquantel	35 mg/kg/day*3 days	RX C2019-16
27/9/2019	2019-51	22	Au Tau	Tilapia	2019-51	Lesion on the skin	Correct water quality issue		
27/9/2019	2019-49	13	Yuen Long	Jade perch		Parasite	Antibiotic prescribed		
30/09/2019	2019-52	12	Hok Tau / Fanling	Tilapia and jade perch		Water quality, parasite (trichodina)	Correct water quality issue		
02/10/2019	2019-52	12	Hok Tau / Fanling	Tilapia		Water quality, parasite (trichodina)	Correct water quality issue		
04/10/2019	2019-53	13	Yuen Long	Managuense	2019-53	New batch arrived			
16/10/2019	2019-54	13	Yuen Long	Managuense	2019-54	New batch arrived			
16/10/2019	2019-55	13	Yuen Long	Jade perch	2019-55	Lesion on the skin	Correct water quality issue		
18/10/2019	2019-56	23	Tin Shui Wai	Marbled eel	2019-56	Do water quality test	Correct water quality issue		
21/10/2019	2019-54	13	Yuen Long	Managuense	2019-54	New batch arrived			
21/10/2019	2019-55	13	Yuen Long	Jade perch	2019-55	Lesion on the skin	Correct water quality issue		
22/10/2019	2019-57	15	Lamma Island	Batfish	2019-57	Mortality			
22/10/2019	2019-58	15	Lamma Island	Red snapper	2019-58	Mortality			
22/10/2019	2019-59	15	Lamma Island	Grunt	2019-59	Mortality			
24/10/2019	2019-60	23	Tin Shui Wai	Mable Goby	2019-60	New batch arrive			
24/10/2019	2019-54	13	Yuen Long	Managuense	2019-54	New batch arrived			
25/10/2019	2019-61	23	Tin Shui Wai	Grouper	2019-61	New batch arrive			
28/10/2019	2019-62	13	Yuen Long	Jade perch	2019-62	White spot and lesion			
28/10/2019	2019-54	13	Yuen Long	Managuense		Revisit	Follow up		
28/10/2019	2019-55	13	Yuen Long	Jade perch		Revisit	Follow up		
28/10/2019	2019-63	24	Yuen Long	Jade perch	2019-63	Gill fester and red spot on the body			
30/10/2019	2019-64	25	Yuen Long	Mitten crabs	2019-64				
5/11/2019	2019-55	13	Yuen Long	Jade perch	2019-55	Recheck low chronic mortality	Follow up		
5/11/2019	2019-54	13	Yuen Long	Managuense	2019-54	Recheck after formalin treatment			
12/11/2019	2019-65	26	Lamma Island	Grouper	2019-65	Mortality	EMB prescribed	50 ug/kg/day*7 days	RX C2019-17
18/11/2019	2019-65	26	Lamma Island	Grouper	2019-65	Recheck slice treatment and pump			
19/11/2019	2019-66	27	Kau Sai Wan	Star snapper /Grouper	2019-66	Mortality			
25/11/2019	2019-65	26	Lamma Island	Grouper	2019-65	Recheck slice treatment and pump			
26/11/2019	2019-66	27	Kau Sai Wan	Grouper	2019-66	Seac lice treatment and pump	EMB prescribed	50 ug/kg/day*7 days	RX C2019-18
27/11/2019	2019-64	25	Yuen Long	Mitten crabs	2019-64	Revisit	Follow up		
29/11/2019	2019-67	38	Yung Shue Au	Pompano	2019-67	Sea lice			
2/12/2019	2019-66	27	Kau Sai Wan	Grouper	2019-66	Recheck sea lice treatment	Follow up	50 ug/kg/day*7 days	RX C2019-18b

4/12/2019	2019-65	26	Lamma Island	Grouper	2019-65	Recheck sea lice treatment and sample collection	Follow up		
09/12/2019	2019-65	26	Lamma Island	Grouper	2019-65	Recheck sea lice treatment and sample collection	Follow up		
11/12/2019	2019-68	13	Yuen Long	Jade perch	2019-68	Meeting with Bruce	None		
13/12/2019	2019-66	27	Kau Sai Wan	Grouper	2019-66	Recheck sea lice treatment	Follow up		
17/12/2019	2019-66	27	Kau Sai Wan	Grouper	2019-66	Recheck sea lice treatment	Follow up		
17/12/2019	2019-69	33	San Tin	Shrimp	2019-69	Mortality			
18/12/2019	2019-70	2	Tai Po	Pompano	2019-70				
18/12/2019	2019-69	33	San Tin	Shrimp		Revisit			
23/12/2019	2019-66	27	Kau Sai Wan	Grouper	2019-66	Recheck sea lice treatment	Follow up		
27/12/2019	2019-72	28	San Tin	Jade perch	2019-72				
27/12/2019	2019-69	33	San Tin	Shrimp	2019-69	Mortality			
30/12/2019	2019-71	18	Sam Mun Tsai	Pompano	2019-71	Lesion on the gill			
31/12/2019	2019-66	27	Kau Sai Wan	Grouper	2019-66	Recheck sea lice treatment	Follow up		
06/01/2020	2020-01	29	Mui Wo	Jade perch	2020-01	New site visit	None		
06/01/2020	2020-02	30	Pui O	Grass carp	2020-02	New site visit	None		
09/01/2020	2019-66	27	Kau Sai Wan	Grouper		Recheck slice treatment	Emamectin benzoate treatment	50 ug/kg/day*7 days	C2019-18C
10/01/2020	2019-71	18	Sam Mun Tsai	Pompano	2019-71	Recheck parasite	Follow up		
17/01/2020	2020-03	13	Yuen Long	Jade perch	2020-03	White spot parasites	Saltwater bath		
17/01/2020	2020-04	13	Yuen Long	Jade perch	2020-04	New fish egg arrive	Monitor fish egg		
20/01/2020	2020-03	13	Yuen Long	Jade perch	2020-03	White spot parasites	Follow up		
20/01/2020	2020-04	13	Yuen Long	Jade perch	2020-04	New fish egg arrive	Follow up		
21/01/2020	2019-66	27	Kau Sai Wan	Grouper	2019-66	Recheck slice treatment	Follow up		
22/1/2020	2019-69	13	Yuen Long	Shrimp	2019-69	Revisit	Follow up		
17/02/2020	2020-05	6	Lau Fau Shan	Grouper	2020-05	Lesion on the body	Correct water quality issue		
17/02/2020	2020-06	13	Yuen Long	Jade perch fry	2020-06	Check for fry	Follow up		
17/02/2020	2020-07	13	Yuen Long	Jade perch	2020-07	Check water quality	Correct water quality issue		
25/02/2020	2020-06	13	Yuen Long	Jade perch fry	2020-06	Recheck for fry	Follow up		
3/2/2020	2020-06	13	Yuen Long	Jade perch fry	2020-06	Recheck for fry	Follow up		
17/03/2020	2020-08	31	Cheung Sha Wan	Hybrid grouper	2020-08	Lesion on the body and sea lice	Follow up		
17/03/2020	2020-09	32	Cheung Sha Wan	Star snapper	2020-09	Gill parasite	Follow up		
18/03/2020	2020-10	33	San Tin	四大家族	2020-10	Water quality check	Correct water quality issue		

18/03/2020	2020-11	34	Yuen Long	Jade perch	2020-11	Water quality check	Correct water quality issue		
19/03/2020	2019-72	28	San Tin	Jade perch	2019-72		Follow up		
19/03/2020	2020-12	28	San Tin	Jade perch fish fry	2020-12	Water quality check	Correct water quality issue		
19/03/2020	2020-13	28	San Tin	Tilapia	2020-13	Water quality check	Correct water quality issue		
23/3/2020	2020-14	29	Mui Wo	Jade perch	2020-14	Build up the bio filter			
24/3/2020	2020-15	13	Yuen Long	Jade perch		Parasite	Saltwater bath		
25/3/2020	2020-16	35	Nam Sang Wai	Jade perch	2020-16	Water quality and parasite check	Correct water quality issue		
25/3/2020	2020-17	36	Nam Sang Wai	Jade perch	2020-17	Water quality check	Correct water quality issue		
26/3/2020	2019-46	21	San Tin	Jade perch / Mullet	2019-46	Water quality check	Follow up		
30/3/2020	2020-06	13	Yuen Long	Jade perch	2020-06	Water quality check	Correct water quality issue		
30/3/2020	2020-18	6	Lau Fau Shan	Grouper	2020-18	Mortality	Follow up		
4/1/2020	2020-08	31	Cheung Sha Wan	Hybrid grouper	2020-08	Sea lice	EMB treatment	50 ug/kg/day*7 days	C2020-01
4/2/2020	2020-19	37	Tai Tau Chau	Hybrid grouper	2020-19	Sea lice	EMB treatment		
4/6/2020	2020-19	37	Tai Tau Chau	Hybrid grouper	2020-19	Sea lice treatment Day 0	EMB treatment	50 ug/kg/day*7 days	C2020-02
4/7/2020	2020-13	28	San Tin	Tilapia	2020-13	Mortality	Correct water quality issue		
4/8/2020	2020-08	31	Cheung Sha Wan	Hybrid grouper	2020-08	Sea lice treatment Day 7	EMB treatment		
4/8/2020	2020-06	13	Yuen Long	Jade perch	2020-06	Mortality	Correct water quality issue		
4/8/2020	2020-20	6	Lau Fau Shan	Grouper			Follow up		
14/4/2020	2020-19	37	Tai Tau Chau	Hybrid grouper	2020-19	Sea lice treatment Day 7	EMB treatment		
14/4/2020	2020-21	19	Tai Tau Chau	Hybrid grouper	2020-21	Sea lice	EMB treatment		
15/4/2020	2020-08	31	Cheung Sha Wan	Hybrid grouper	2020-08	Sea lice treatment Day 14	EMB treatment		
15/4/2020	2020-06	13	Yuen Long	Jade perch	2020-06	Red spot on the body	OTC treatment	100 mg/kg/day*10 days	C2020-03
20/4/2020	2020-06	13	Yeun Long	Jade perch	2020-06	Mortality	Follow up		
20/4/2020	2020-22	6	Lau Fau Shan	Grouper	2020-22	Lesion	Correct water quality issue		
21/4/2020	2020-19	15	Tai Tau Chau	Hybrid grouper	2020-19	Treatment Day 14	EMB treatment		
21/4/2020	2020-21	16	Tai Tau Chau	Hybrid grouper		Sea lice	EMB treatment	50 ug/kg/day*7 days	C2020-04
21/4/2020	2020-23	17	Tai Tau Chau	Hybrid grouper	2020-23	Sea lice	Collect sea lice sample		
22/4/2020	2020-08	7	Cheung Sha Wan	Hybrid grouper	2020-08	Treatment Day 21	EMB treatment	50 ug/kg/day*7 days	C2020-01B
23/4/2020	2020-24	6	Lau Fau Shan	Grouper		Lesion	Correct water quality issue		
27/4/2020	2020-06(1)	13	Yeun Long	Jade perch		Mortality	Praziquantel treatment	35 mg/kg/day*3 days	C2020-05
27/4/2020	2020-06(2)	13	Yeun Long	Jade perch		Mortality	OTC treatment	100 mg/kg/day*10 days	C2020-06
28/04/2020	2020-19	15	Tai Tau Chau	Hybrid grouper	2020-19	Treatment Day 21	EMB treatment	50 ug/kg/day*7 days	C2020-02B
28/04/2020	2020-21	16	Tai Tau Chau	Hybrid grouper	2020-21	Treatment Day 0	Follow up		

28/4/2020	2020-06(1)	13	Yeun Long	Jade perch		Mortality	Follow up		
28/4/2020	2020-06(2)	13	Yeun Long	Jade perch		Dactylogyrus spp	Follow up		
29/04/2020	2020-11	10	Yuen Long	Jade perch	2020-11	Mortality	Correct water quality issue		
5/4/2020	2020-06(3)	13	Yuen Long	Jade perch fry		Dactylogyrus spp	Praziquantel treatment	50 mg/kg/day*3 days	RX C2020-07
5/4/2020	2020-06(2)	13	Yuen Long	Jade perch fry		Dactylogyrus spp	Praziquantel treatment	50 mg/kg/day*3 days	RX C2020-06B
5/5/2020	2020-21	16	Tai Tau Chau	Hybrid grouper	2020-21	Treatment Day 7	Follow up		
5/6/2020	2020-25	18	San Tin	Jade perch	2020-25	Water quality check	Correct water quality issue		
5/12/2020	2020-21	16	Tai Tau Chau	Hybrid grouper	2020-21	Treatment Day 14	Follow up		
14/5/2020	2020-06(3)	13	Yuen Long	Jade perch fry	2020-06(3)	Dactylogyrus spp	Follow up		
15/05/2020	2020-26	41	So Kwun Wat	Jade perch	2020-26	Ich and trichodina	Salt bath		
18/05/2020	2020-27	16	Mai Po	Mullet	2020-27	Water quality trial			
18/5/2020	2020-06(3)	13	Yuen Long	Jade perch fry	2020-06(3)	Dactylogyrus spp	Follow up		
18/5/2020	2020-15	13	Yuen Long	Jade perch	2020-15	Water quality check	Correct water quality issue		
19/05/2020	2020-19	37	Tai Tau Chau	Hybrid grouper	2020-19	Treatment Day 42	Follow up		
19/05/2020	2020-21	19	Tai Tau Chau	Hybrid grouper	2020-21	Treatment Day 21	Follow up		
20/05/2020	2020-28	42	San Tin	Mullet	2020-28	Water quality trial			
20/05/2020	2020-29	43	Yuen Long	Jade perch	2020-29	Water quality check	Correct water quality issue		
25/05/2020	2020-27	16	Mai Po	Mullet	2020-27	Water quality trial			
26/05/2020	2020-21	19	Tai Tau Chau	Hybrid grouper	2020-21	Treatment Day 28	Follow up		
27/05/2020	2020-28	42	San Tin	Mullet		Water quality trial			
27/05/2020	2020-30	22	Au Tau	Jade perch		Fry mortality	Correct water quality issue		
29/05/2020	2020-26	41	So Kwun Wat	Jade perch	2020-26	Ich and trichodina	Salt bath		
29/05/2020	2020-12	28	San Tin	Jade perch	2020-12	Mortality	Correct water quality issue		
6/1/2020	2020-27	16	Mai Po	Mullet		Water quality trial			
6/1/2020	2020-31	44	Tai Sang Wai	Mullet	2020-31	Mortality	Correct water quality issue		
6/2/2020	2020-12	28	San Tin	Jade perch		Water quality check	Correct water quality issue		
6/3/2020	2020-28	42	San Tin	Mullet		Water quality trial			
6/8/2020	2020-06(3)	13	Yuen Long	Jade perch fry		Dactylogyrus spp	Follow up		
6/9/2020	2020-27	16	Mai Po	Mullet		Water quality trial			
6/9/2020	2020-32	15	Lamma Island	Cobia	2020-32	Water quality issue			
6/10/2020	2020-28	42	San Tin	Mullet		Water quality trial			
6/10/2020	2020-33	34	Yuen Long	Jade perch fry	2020-33	Mortality	Correct water quality issue		

6/10/2020	2020-34	34	Yuen Long	Mud carp	2020-34	Mortality	Correct water quality issue		
15/06/2020	2020-12	28	San Tin	Jade perch	2020-12	Follow up			
15/06/2020	2020-35	28	San Tin	Jade perch fry	2020-35	Water quality check			
15/6/2020	2020-36	45	Tai Po	Jade perch fry	2020-36	Dactylogyrus spp and Ich	Salt bath		
16/06/2020	2020-27	16	Mai Po	Mullet		Water quality trial			
16/06/2020	2020-33	34	Yuen Long	Jade perch fry	2020-33	Follow up			
16/06/2020	2020-34	34	Yuen Long	Mud carp	2020-34	Follow up			
16/06/2020	2020-11	34	Yuen Long	Jade perch	2020-11	Follow up			
17/06/2020	2020-28	42	San Tin	Mullet		Water quality trial			
18/6/2020	2020-06(3)	13	Yuen Long	Jade perch fry	2020-06(3)	Dactylogyrus spp	Praziquantel treatment	50 mg/kg/day*3 days	RX C2020-08
22/06/2020	2020-27	16	Mai Po	Mullet		Water quality trial			
22/6/2020	2020-36	45	Tai Po	Jade perch fry	2020-36	Dactylogyrus spp and Ich	Follow up		
23/06/2020	2020-12	28	San Tin	Jade perch	2020-12	Follow up			
23/06/2020	2020-35	28	San Tin	Jade perch fry	2020-35	Follow up			
23/6/2020	2020-06(3)	13	Yuen Long	Jade perch fry		Dactylogyrus spp	Follow up		
23/6/2020	2020-06(2)	13	Yuen Long	Jade perch fry		Dactylogyrus spp	Follow up		
23/6/2020	2020-37	13	Yuen Long	Jade perch fish fry	2020-37	Dactylogyrus spp	Follow up		
24/06/2020	2020-28	42	San Tin	Mullet		Water quality trial			
24/06/2020	2020-33	34	Yuen Long	Jade perch fry		Follow up			
24/06/2020	2020-34	34	Yuen Long	Mud carp		Follow up			
24/06/2020	2020-11	34	Yuen Long	Jade perch		Follow up			
26/06/2020	2020-38	47	Fanling	Jade Perch	2020-38	Trichodina	Salt bath		
26/06/2020	2020-32	15	Lamma Island	Cobia	2020-32	Water quality issue			
29/06/2020	2020-27	16	Mai Po	Mullet		Water quality trial			
29/6/2020	2020-06(3)	13	Yuen Long	Jade perch fry		Follow up			
29/6/2020	2020-06(2)	13	Yuen Long	Jade perch fry		Follow up			
29/6/2020	2020-37	13	Yuen Long	Jade perch fish fry	2020-37	Follow up			
30/06/2020	2020-28	42	San Tin	Mullet		Water quality trial			
30/06/2020	2020-12	28	San Tin	Jade perch		Follow up			
30/06/2020	2020-35	28	San Tin	Jade perch fry		Follow up			
30/06/2020	2020-39	2	Tai Po	Batfish	2020-39	Cryptocaryon irritans	Formalin bath		
7/2/2020	2020-32	15	Lamma Island	Cobia	2020-32	Mortality			

7/3/2020	2020-40	48	Tai Po	Jede perch	2020-40	Water quality test	Water changing		
7/6/2020	2020-27	16	Mai Po	Mullet		Water quality trial			
7/6/2020	2020-06(3)	13	Yuen Long	Jade perch fry		Follow up			
7/6/2020	2020-06(2)	13	Yuen Long	Jade perch fry		Follow up			
7/6/2020	2020-37	13	Yuen Long	Jade perch fish fry		Follow up			
7/6/2020	2020-41	13	Yuen Long	Jade perch fish fry		Follow up			
7/7/2020	2020-42	49	Sandy Ridge	Tilapia	2020-42	Water quality test	No		
7/7/2020	2020-12	28	San Tin	Jade perch	2020-12	Follow up			
7/7/2020	2020-35	28	San Tin	Jade perch fry	2020-35	Follow up			
7/8/2020	2020-28	42	San Tin	Mullet		Water quality trial			
7/8/2020	2020-40	48	Tai Po	Jade Perch		Follow up			
7/9/2020	2020-43	6	Lau Fau Shan	Grouper	2020-43	Mortality			
7/10/2020	2020-38	47	Fanling	Jade Perch	2020-38	Follow up			
7/10/2020	2020-40	48	Tai Po	Jade Perch	2020-40	Follow up			
13/07/2020	2020-27	16	Mai Po	Mullet		Water quality trial			
13/7/2020	2020-37	13	Yuen Long	Jade perch fish fry		Follow up			
13/7/2020	2020-44	13	Yuen Long	Jade perch fish fry		Fish heath check-moderate levels of ich	-Formalin treatment -Cupramine treatment		
14/07/2020	2020-12	28	San Tin	Jade perch		Follow up			
14/07/2020	2020-35	28	San Tin	Jade perch fry		Follow up			
14/07/2020	2020-45	46	Yuen Long	Mullet	2020-45	Water quality check	Water changing		
15/07/2020	2020-28	42	San Tin	Mullet		Water quality trial			
15/07/2020	2020-40	48	Tai Po	Jade Perch		Follow up			
17/07/2020	2020-46	51	Yung Shue Au	Batfish	2020-46	Fish heath check	Water changing		
20/07/2020	2020-27	16	Mai Po	Mullet		Water quality trial			
20/07/2020	2020-47	33	San Tin	Jade Perch	2020-47	Mortality	Correct water quality issue		
21/07/2020	2020-45	46	Yuen Long	Mullet	2020-45	Follow up			
21/07/2020	2020-12	28	San Tin	Jade Perch	2020-12	Follow up			
21/07/2020	2020-35	28	San Tin	Jade perch fry	2020-35	Follow up			
22/07/2020	2020-28	42	San Tin	Mullet		Water quality trial			
22/7/2020	2020-37	13	Yuen Long	Jade perch fish fry	2020-37	Follow up			
22/7/2020	2020-44	13	Yuen Long	Jade perch fish fry	2020-44	Follow up			

27/07/2020	2020-27	16	Mai Po	Mullet		Water quality trial			
27/07/2020	2020-47	33	San Tin	Jade Perch	2020-47	Mortality	Correct water quality issue		
27/07/2020	2020-48	52	San Tin	Mullet	2020-48	Water quality check	Correct water quality issue		
27/07/2020	2020-49	53	San Tin	Mullet	2020-49	Water quality check	Correct water quality issue		
28/07/2020	2020-45	46	Yuen Long	Mullet		Follow up			
28/07/2020	2020-50	13	Yuen Long	Jade Perch	2020-50	Fish heath check-parasite	-Increase salinity - Formalin treatment - Cupramine treatment - Increase oxygenation support due to parasite load.		
28/07/2020	2020-12	28	San Tin	Jade perch		Follow up			
28/07/2020	2020-35	28	San Tin	Jade perch fry		Follow up			
28/07/2020	2020-13	28	San Tin	Tilapia		Follow up			
29/07/2020	2020-28	42	San Tin	Mullet		Water quality trial			
29/07/2020	2020-51	54	Ma Tso Lung	Mullet	2020-51	Mortality	Correct water quality issue		
31/07/2020	2020-52	55	Ma Tso Lung	Mullet	2020-52	Mortality	Correct water quality issue		
31/07/2020	2020-53	26	Lamma Island	Hybrid grouper	2020-53	Dactylogyrus spp	Praziquantel treatment	35 mg/kg/day*3 days	RX C2020-09
8/3/2020	2020-27	16	Mai Po	Mullet		Water quality trial			
8/3/2020	2020-47	33	San Tin	Jade perch		Follow up			
8/3/2020	2020-54	56	San Tin	Mullet	2020-54	Water quality check	No		
8/4/2020	2020-45	46	Yuen Long	Mullet		Follow up			
8/4/2020	2020-50	13	Yuen Long	Jade perch		Follow up			
8/4/2020	2020-12	28	San Tin	Jade perch		Follow up			
8/4/2020	2020-35	28	San Tin	Jade perch		Follow up			
8/4/2020	2020-13	28	San Tin	Tilapia		Follow up			
8/5/2020	2020-28	42	San Tin	Mullet		Water quality trial			
8/5/2020	2020-51	54	Ma Tso Lung	Mullet		Follow up			
8/7/2020	2020-55	57	Mai Po	Tilapia, grey mullet, bighead	2020-55	Water quality check	On site water quality measurement revealed water		
8/7/2020	2020-56	58	Ngau Tam Mei	Tilapia, grey mullet and jade perch	2020-56	Water quality check	Reduce feed,Water exchange,Increase aeration		
8/7/2020	2020-57	59	Ngau Tam Mei	Tilapia		Water quality check	Water exchange,Reduce feeding,Removal of bottom waste and excess feed from bottom of the pond		

8/10/2020	2020-27	16	Mai Po	Mullet		Water quality trial				
8/10/2020	2020-47	33	San Tin	Jade perch		Follow up				
8/11/2020	2020-45	46	Yuen Long	Mullet		Follow up				
8/11/2020	2020-58	13	Yuen Long	Jade perch fry	2020-58	Follow up				
8/11/2020	2020-12	28	San Tin	Jade perch		Follow up				
8/11/2020	2020-35	28	San Tin	Jade perch fry		Follow up				
8/11/2020	2020-13	28	San Tin	Tilapia		Follow up				
8/12/2020	2020-28	42	San Tin	Mullet		water quality trial				
8/12/2020	2020-59	60	Yuen Long	Jade perch	2020-59	Water quality check	Increase aeration, reduce feeding and removal bottom waste / remain feed			
17/08/2020	2020-27	16	Mai Po	Mullet		Water quality trial				
17/08/2020	2020-47	33	San Tin	Jade perch		Follow up				
17/08/2020	2020-60	33	San Tin	Shrimp		Water quality check	Prepare pumps to introduce ST050 pond water to help increase water levels at ST053.			
18/08/2020	2020-45	46	Yuen Long	Mullet		Follow up				
18/08/2020	2020-58	13	Yuen Long	Jade perch fry		Follow up				
18/08/2020	2020-12	28	San Tin	Jade perch		Follow up				
18/08/2020	2020-35	28	San Tin	Jade perch fry		Follow up				
18/08/2020	2020-13	28	San Tin	Tilapia		Follow up				
21/08/2020	2020-28	42	San Tin	Mullet		Water quality trial				
21/08/2020	2020-61	17	Mai Po	Mullet	2020-61	Mortality	1) Reduce feed 2) Prompt removal of obvious dead fish 3) Increase aeration 10:00 to 16:00 hours and 20:00 hours to 08:00 hours of the following day			
24/08/2020	2020-27	16	Mai Po	Mullet		Water quality trial				
25/08/2020	2020-12	28	San Tin	Jade perch		Follow up				
25/08/2020	2020-35	28	San Tin	Jade perch fry		Follow up				
25/08/2020	2020-13	28	San Tin	Tilapia		Follow up				
25/08/2020	2020-47	33	San Tin	Jade perch		Follow up				
25/08/2020	2020-60	33	San Tin	Shrimp		Follow up				
26/08/2020	2020-28	42	San Tin	Mullet		Water quality trial				

26/08/2020	2020-62	13	Yuen Long	Jade perch fry	2020-62	Fish heath check			
28/08/2020	2020-47	33	San Tin	Jade perch		Follow up			
28/08/2020	2020-63	23	Tin Shui Wai	Mable Goby	2020-63	Water quality check	On site water quality measurement revealed water		
31/08/2020	2020-27	16	Mai Po	Mullet		Water quality trial			
31/08/2020	2020-64	6	Lau Fau Shan	Grouper	2020-64	Lesion			
9/1/2020	2020-47	33	San Tin	Jade perch		Follow up			
9/1/2020	2020-60	33	San Tin	Shrimp		Follow up			
9/1/2020	2020-65	61	Yuen Long	Mullet		Mortality	Commended farmer for monitoring pH . Advise to continue to do so esp with any weathr change) upcoming rain) Aerator to be turned on more in 11a. Unable to explain acidity in the NSW12 pond. IN face it is the NSW 12 b (further pond) that is more acidic, not the near pond. Farmer to call us for any adverse findings and advised to monitor pH and DO as frequently as he can		
9/2/2020	2020-28	42	San Tin	Mullet		Water quality trial			
9/2/2020	2020-66	13	Yuen Long	Jade perch fry		Fish heath check			
9/7/2020	2020-27	16	Mai Po	Mullet		Water quality trial			
9/7/2020	2020-47	33	San Tin	Jade perch		Follow up			
9/7/2020	2020-60	33	San Tin	Shrimp		Follow up			
9/8/2020	2020-12	28	San Tin	Jade perch		Follow up			
9/8/2020	2020-35	28	San Tin	Jade perch fry		Follow up			
9/8/2020	2020-13	28	San Tin	Tilapia		Follow up			
9/8/2020	2020-66	13	Yuen Long	Jade perch fry		Follow up			
9/8/2020	2020-28	42	San Tin	Mullet		Water quality trial			
9/9/2020	2020-67	33	San Tin	Shrimp		Water quality check			
9/9/2020	2020-68	56	San Tin	Mullet		Water quality check			
9/9/2020	2020-65	61	Yuen Long	Mullet		Follow up			
9/11/2020	2020-58	13	Yuen Long	Jade perch fry		Follow up	Florfenicol treatment	35 mg/kg/day*7 days	RX C2020-10
14/09/2020	2020-27	16	Mai Po	Mullet		Water quality trial			
14/09/2020	2020-58	13	Yuen Long	Jade perch fry	2020-58	Follow up	Oxytetracycline treatment	50 mg/kg/day*10 days	RX C2020-11*3
15/09/2020	2020-12	28	San Tin	Jade perch		Follow up			

15/09/2020	2020-35	28	San Tin	Jade perch fry		Follow up			
15/09/2020	2020-13	28	San Tin	Tilapia		Follow up			
16/09/2020	2020-28	42	San Tin	Mullet		Water quality trial			
16/09/2020	2020-60	33	San Tin	Shrimp		Follow up			
16/09/2020	2020-69	33	San Tin	Jade perch		Water quality check	1) Application of lime 2) Increase aeration 3) Normal feeding		
16/09/2020	2020-65	61	Yuen Long	Mullet		Follow up			
18/09/2020	2020-70	62	Chai Wan	Jade perch	2020-70	Mortality	Stop feeding until we start medication tomorrow - Antibiotics in feed – Oxytetracycline (OTC 45%) 50 mg/kg sid x 7 days Drug dispensed after accounting for fish death: CF3- 270 fish x 26 g - 7 kg biomass (0.8g/day) CF1 - 37 fish x 120 g - 4.5 kg biomass (0.5g/day) Module B - 60 fish x 150 g - 9 kg biomass (1 g/day)	50 mg/kg/day*10 days	RX C2020-12a-c
21/09/2020	2020-27	16	Mai Po	Mullet		Water quality trial			
21/09/2020	2020-60	33	San Tin	Shrimp		Follow up			
21/09/2020	2020-69	33	San Tin	Jade perch		Follow up			
21/09/2020	2020-58	13	Yuen Long	Jade perch fry		Follow up			
22/09/2020	2020-70	62	Chai Wan	Jade perch		Follow up			
23/09/2020	2020-28	42	San Tin	Mullet		Water quality trial			
25/09/2020	2020-12	28	San Tin	Jade perch		Follow up			
25/09/2020	2020-35	28	San Tin	Jade perch fry		Follow up			
25/09/2020	2020-13	28	San Tin	Tilapia		Follow up			
28/09/2020	2020-58	13	Yuen Long	Jade perch fry		Follow up			
29/09/2020	2020-70	62	Chai Wan	Jade perch		Follow up			

30/09/2020	2020-71	16	Mai Po	Mullet	2020-71	Mortality	Water monitor by farmer. Owner may get more equipment and he is getting probes. Will follow up with lesson.talk on pH, TAN etc important water parameters to monitor Increase aeration advised.		
30/09/2020	2020-72	13	Yuen Long	Jade perch fry	2020-72	Fish heath check	Salinity elevation to 5-6ppt		
30/09/2020	2020-12	28	San Tin	Jade perch		Follow up			
30/09/2020	2020-35	28	San Tin	Jade perch fry		Follow up			
30/09/2020	2020-13	28	San Tin	Tilapia		Follow up			
10/5/2020	2020-70	62	Chai Wan	Jade perch	2020-70	Follow up			
10/6/2020	2020-12	28	San Tin	Jade perch	2020-12	Follow up			
10/6/2020	2020-35	28	San Tin	Jade perch fry	2020-35	Follow up			
10/6/2020	2020-13	28	San Tin	Tilapia	2020-13	Follow up			
10/6/2020	2020-72	13	Yuen Long	Jade perch fry		Follow up			
10/7/2020	2020-71	16	Mai Po	Mullet		Follow up			
10/9/2020	2020-65	61	Yuen Long	Mullet		Follow up			
10/12/2020	2020-12	28	San Tin	Jade perch		Follow up			
10/12/2020	2020-35	28	San Tin	Jade perch fry		Follow up			
10/12/2020	2020-13	28	San Tin	Tilapia		Follow up			
10/12/2020	2020-72	13	Yuen Long	Jade perch fry		Follow up			
14/10/2020	2020-65	61	Yuen Long	Mullet		Follow up			
15/10/2020	2020-73	3	Sai Kung	Grouper	2020-73	Lesion in the mouth -Sea lice	Formalin Bath		
19/10/2020	2020-70	62	Chai Wan	Jade perch		Follow up			
20/10/2020	2020-65	61	Yuen Long	Mullet		Follow up			
21/10/2020	2020-73	3	Sai Kung	Grouper	2020-73	Follow up			
21/10/2020	2020-72	13	Yuen Long	Jade perch fry		Follow up			
23/10/2020	2020-35	28	San Tin	Jade perch fry		Follow up			
23/10/2020	2020-13	28	San Tin	Tilapia		Follow up			
27/10/2020	2020-72	13	Yuen Long	Jade perch fry	2020-72	Follow up	Oxytetracycline treatment	50 mg/kg/day*7 days	RX C2020-13
27/10/2020	2020-60	33	San Tin	Shrimp		Follow up			
27/10/2020	2020-69	33	San Tin	Jade perch		Follow up			
30/10/2020	2020-74	63	Fanling	Tilapia and Jade perch	2020-74	Water quality check			

11/2/2020	2020-72	13	Yuen Long	Jade perch fry	2020-72	Follow up	Oxytetracycline treatment	100 mg/kg/day*7 days	RX C2020-13b
11/6/2020	2020-75	64	Yuen Long	Jade perch	2020-75	Water quality check	1) Reduce stocking density2) Water exchange		
11/9/2020	2020-76	26	Lamma Island	Hybrid grouper	2020-76	Skin lesion	1)Increase water exchange rate within the nursery system 2)Maintain current feeding rate at 2.5% for another 5-7 days until fish conditions are mostly normal and minimal morbidity and mortality. 3)Removal of sick and moribund fish 4)Future cohort importation can consider acquiring smaller size fry (2-3g size) for easier acclimatization		
11/10/2020	2020-65	61	Yuen Long	Mullet		Mortality	Advise when weather is ok,(raining these few days), consider moving fish from near side 12.		
11/10/2020	2020-69	33	San Tin	Jade perch		Follow up			
11/11/2020	2020-35	28	San Tin	Jade perch fry		Follow up			
11/11/2020	2020-13	28	San Tin	Tilapia		Follow up			
13/11/2020	2020-65	61	Yuen Long	Mullet		Follow up			
13/11/2020	2020-69	33	San Tin	Jade perch		Follow up			
18/11/2020	2020-65	61	Yuen Long	Mullet		Follow up			
18/11/2020	2020-69	33	San Tin	Jade perch		Follow up			
20/11/2020	2020-65	61	Yuen Long	Mullet		Follow up			
20/11/2020	2020-72	13	Yuen Long	Jade perch fry	2020-72	Mortality			
23/11/2020	2020-65	61	Yuen Long	Mullet		Follow up			
23/11/2020	2020-40	48	Tai Po	Jade perch		Water quality check			
24/11/2020	2020-72	13	Yuen Long	Jade perch fry	2020-72	Follow up	Oxytetracycline treatment	100 mg/kg/day*7 days	RX C2020-14
25/11/2020	2020-77	26	Lamma Island	Hybrid grouper	2020-77	Skin lesion	Stop feeding		
9/12/2020	2020-78	13	Yuen Long	Jade perch		Check RAS			

Appendix D

List of Clients

Client name	General location	Contact number	Type of system
AFCD	Au Tau	[redacted]	Pond
[redacted]	Chai Wan	[redacted]	RAS(fresh water)
[redacted]	Cheung Sha Wan	[redacted]	Marine
[redacted]	Cheung Sha Wan	[redacted]	Marine
[redacted]	Cheung Sha Wan	[redacted]	Marine
[redacted]	Fanling	[redacted]	Pond
[redacted]	Fanling	[redacted]	Pond
[redacted]	Fanling	[redacted]	Pond
[redacted]	Hok Tau / Fanling	[redacted]	RAS(fresh water)
[redacted]	Kau Sai Wan	[redacted]	Marine
[redacted]	Kowloon Tong	[redacted]	RAS(fresh water)
[redacted]	Kowloon Tong	[redacted]	RAS
[redacted]	Lamma Island	[redacted]	Marine
[redacted]	Lamma Island	[redacted]	Marine
[redacted]	Lamma Island	[redacted]	Marine
[redacted]	Lau Fau Shan	[redacted]	RAS(salt water)
[redacted]	Lau Fau Shan	[redacted]	Pond
[redacted]	Ma Tso Lung	[redacted]	Pond
[redacted]	Ma Tso Lung	[redacted]	Pond
[redacted]	Mai Po	[redacted]	Pond
[redacted]	Mai Po	[redacted]	Pond
[redacted]	Mai Po	[redacted]	Pond
[redacted]	Mai Po	[redacted]	Pond
[redacted]	Mai Po	[redacted]	RAS(fresh water)
[redacted]	Mui Wo	[redacted]	RAS(fresh water)
[redacted]	Nam Sang Wai	[redacted]	Pond
[redacted]	Nam Sang Wai	[redacted]	Pond
[redacted]	Ngau Tam Mei	[redacted]	Pond
[redacted]	Ngau Tam Mei	[redacted]	Pond
[redacted]	Pui O	[redacted]	Pond
[redacted]	Sai Kung	[redacted]	Marine
[redacted]	Sai Kung	[redacted]	Marine
[redacted]	Sam Mun Tsai	[redacted]	Marine
[redacted]	Sam Mun Tsai	[redacted]	Marine
[redacted]	San Tin	[redacted]	Pond
[redacted]	San Tin	[redacted]	Pond
[redacted]	San Tin	[redacted]	Pond
[redacted]	San Tin	[redacted]	Pond
[redacted]	San Tin	[redacted]	Pond
[redacted]	San Tin	[redacted]	Pond
[redacted]	San Tin	[redacted]	Pond
[redacted]	San Tin	[redacted]	Pond
[redacted]	Sandy Ridge	[redacted]	Pond
[redacted]	So Kwun Wat	[redacted]	RAS(fresh water)

[redacted]		Tai Po	[redacted]	Marine
[redacted]		Tai Po	[redacted]	Marine
[redacted]		Tai Po	[redacted]	Marine
[redacted]		Tai Po	[redacted]	RAS(fresh water)
[redacted]		Tai Po	[redacted]	Pond
[redacted]		Tai Sang Wai	[redacted]	Pond
[redacted]		Tai Sang Wai	[redacted]	Pond
[redacted]		Tai Tau Chau	[redacted]	Marine
[redacted]		Tai Tau Chau	[redacted]	Marine
[redacted]		Tai Tau Chau	[redacted]	Marine
[redacted]		Tin Shui Wai	[redacted]	RAS
[redacted]		Tung Long Island	[redacted]	Marine
[redacted]		Yim Tin Jai	[redacted]	Marine
[redacted]		Yuen Long	[redacted]	RAS(fresh water)
[redacted]		Yuen Long	[redacted]	RAS(fresh water)
[redacted]		Yuen Long	[redacted]	RAS
[redacted]		Yuen Long	[redacted]	Pond
[redacted]		Yuen Long	[redacted]	RAS(fresh water)
[redacted]		Yuen Long	[redacted]	Pond
[redacted]		Yuen Long	[redacted]	Pond
[redacted]		Yuen Long	[redacted]	Pond
[redacted]		Yung Shue Au	[redacted]	Marine
[redacted]		Yung Shue Au	[redacted]	Marine

Appendix E

Thank you letter from client

Appendix E

[redacted]

18th October,2019

Mr. Lai Kin-ming
Assistant Director (Fisheries)
Agriculture, Fisheries and Conservation Department
5/F, Cheung Sha Wan Government Offices
303 Cheung Sha Wan Road
Kowloon

Letter of Appreciation

Dear Mr. Lai,

We would like to take this opportunity to send our deep gratitude to Dr. Sophie and her team (of vet service) from the City University of Hong Kong. Their professional advises of preparation, cultivation, monitoring and medication are undoubtedly a big help to us to tackle the problems that we can never solve on our own. Their proactive actions and expertise deserve the merits for sure.

At the time we are growing our fish, we will have the Jade Perch fertilized eggs from Australia in mid-November. Bruce Sambell the father of Jade Perch who will be attending our very first time to experiment hatchery in Shipping Container (**MoVertical Farm - Moveable Vertical Farm**) that we would like to share this experience with interested growers and request the technical support and knowledge from your department (Au Tau office). On the one hand, it would help us to grasp the technique to handle fish eggs, and on the other hand it also helps to promote the local fishery industry as we can provide fish fry in early Spring and continue to supply throughout the season. So growers need not to wait for another season.

As a government department for fishery, we wish to have your practical supports for development which is good to the community.

We look forwards to hearing from you soon. Please feel free to contact me on [redacted] or email: [redacted]

Thank you very much.

[redacted]

Director
Hong Kong Aquaponic Holdings Limited.
(Member of MoVertical Farm)

C.C. Professor Sophie ST-HILAIRE (ssthilai@cityu.edu.hk)
Ms Ma (AFCD Office Au Tau)

Appendix F

Emamectin Benzoate manuscript

Appendix F

frontiers in Veterinary Science

ORIGINAL RESEARCH
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Emamectin Benzoate Treatment of Hybrid Grouper Infected With Sea Lice in Hong Kong

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Sea lice (Copepoda: Caligidae) are ectoparasites which negatively impact marine aquaculture species around the world. There are a limited number of treatments licensed for use against sea lice in tropical and semi-tropical farmed fish species. Emamectin benzoate (EB) was an effective pharmaceutical drug against sea lice infestations in several salmon industries before resistance to the product developed. This drug has not been extensively tested in marine fish within Asia. The objective of this study was to determine whether this drug could be used to treat oral infections with sea lice in hybrid grouper (*Mycteroperca tigris* × *Epinephelus lanceolatus*) cultured in saltwater net-pen sites in Hong Kong. We observed an overall reduction in sea lice infections over time, starting on the last day of the treatment up to the end of our study (i.e., 14 days after the last EB treatment). We also observed a large variation in concentrations of EB in fish on the last day of the treatment, which provides an explanation for the variation in response to the treatment. It also suggests that distribution of the medication to fish in saltwater net-pens is difficult, especially when medication is hand-mixed in the feed and possibly unevenly distributed in the daily rations. Overall, this study provides preliminary evidence that EB could be used to treat sea lice found in Hong Kong and potentially in other regions of SE Asia.

Keywords: grouper aquaculture, copepodid parasites, *Caligus*, parasite control, emamectin benzoate

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INTRODUCTION

Sea lice are copepod parasites of economically important marine finfish found around the world. Some sea lice species affect only certain species of fish (i.e., *Lepeophtheirus salmonis*), while others, such as those belonging to the genus *Caligus*, are known to be more generalists (1, 2). *Caligus* species can live in a wide range of environments (1, 2). The larval stages of *Caligus* species can survive up to 8 days without food in temperatures ranging from 19 to 26°C (tropical and semi-tropical regions) in both marine and brackish waters (1, 2). In Asia, several species of *Caligus* sea lice, including *Caligus epidemicus*, *C. chiastos*, *C. punctatus*, *C. multispinosus*, and C. *rotundigenitalis* have been reported to infect farmed grouper (3–5).

In Hong Kong, which has a family-based marine aquaculture industry that produces ∼1,000 tons of fish per year (https://www.gov.hk/en/about/abouthk/factsheets/docs/agriculture.pdf) there have been anecdotal reports of unknown species of sea lice affecting farmed hybrid grouper

(*Mycteroperca tigris* × *Epinephelus lanceolatus*) for several years. Unlike the *Caligus* spp. that infect salmon, the sea lice found in Hong Kong are smaller (i.e., 2–4 mm as adults) and they are predominantly localized in the oral cavity of the grouper (**Figure 1**). Infections caused by the sea lice species found in Hong Kong can be severe, cause fish to go off-feed, and lead to mortality (A. Leung, Agriculture, Fisheries and Conservation Department Hong Kong, 2020, Personal Communication). Formalin baths have been used to control this parasite in saltwater net-pens in Hong Kong on a small scale (A. Leung, Agriculture, Fisheries and Conservation Department Hong Kong, 2020, Personal Communication). This product is a carcinogen so these treatments are difficult to administer, and like most bath treatments the effect is not long lasting. Further, because the sea lice in grouper from Hong Kong are located inside the oral cavity, bath treatments are not always as effective as in the salmon industry, where sea lice species are predominantly found on the external surface of fish.

Systemic treatments with a long residual effect, such as with emamectin benzoate (EB), and Teflubenzuron, are not widely

FIGURE 1 | Examples of the range of sea lice infections observed on farms during the emamectin trial. Fish **(A1–A3)** were considered moderate to severe infections (category 2). Fish **(B1–B3)** were considered mild infections (category 1). Fish **(C1–C3)** were considered fish that were not infected or recovered from infection. The black arrow (on fish **A1**) illustrates a chronic lesion associated with sea lice. The red arrow (on fish **B3**) illustrates sea lice clusters (newer infections) with no tissue response. The blue arrow (on fish **C1**) illustrates tissue response in fish which was no longer infected with sea lice (post-treatment).

used to treat sea lice in Hong Kong, despite their frequent use in many salmon industries around the world (6–9). Orally fed EB is distributed in different tissues including the mucus of the fish (10, 11). The drug is taken up by sea lice when it ingests mucus and blood from treated fish. The product disrupts chloride ion movement in nerve cells by blocking glutamate-gated (GluCl) and γ-aminobutyric acid (GABA)-gated (GABA-Cl) chloride channels, which eventually results in the death of the sea lice (12, 13). When EB was first introduced on the market several decades ago the product was very effective against sea lice (*Caligus* spp. and *L. salmonis*) infecting salmon; however, in the last 10 years there have been reports of resistance to EB in most salmon industries around the world (14, 15). The objective of this study was to assess the efficacy of EB on local sea lice parasites infecting the oral cavity of hybrid grouper in Hong Kong saltwater net-pen sites. We report results of sea lice treatments on five independently managed farms in bays surrounding Hong Kong.

MATERIALS AND METHODS

Farm Selection

Hybrid grouper farms around several fish farming regions in Hong Kong affected by sea lice were identified through the diagnostic services of the City University of Hong Kong aquatic animal veterinary service. Farmers were asked to participate in an EB field trial. Farmers participating in our study had between 3 and 10 small (3m by 3m by 3m) net-pens of hybrid grouper. The criteria for inclusion in this study were: (1) that fish had sea lice infections (i.e., microscopic evidence of copepodid parasites in the oral cavity) and no bacteria or other parasitic pathogens as determined by our initial diagnostic work-up; (2) fish were not to be harvested for 21 days post treatment; (3) farms had no crustacean aquaculture species on the site with the hybrid grouper; (4) fish were still eating; and (5) the farmer was willing to withhold at least 30 untreated fish in a separate pen as controls for comparison up to 21 days from the start of the treatment. Our initial diagnostic work-up consisted of a gross necropsy, wet mount scraping of the oral cavity lesions and the gills, and a bacterial culture from the kidney of the fish on blood agar, marine agar (2% salt), and tryptic soy Agar. Gills were examined for evidence of other parasites (i.e., ciliated protozoans, monogeneans, etc) and the kidney bacterial culture was to verify that fish did not have co-infections with bacterial pathogens.

Field Trial Emamectin Benzoate (EB)

Once a farmer agreed to participate in our trial and met the inclusion criteria, five fish were collected, using a dip net (outside their regular feeding period) prior to the start of the administration of EB for a baseline sample (day 0 of experiment). Fish were euthanized with an Ikigun (Auckland, New Zealand), weighed, and externally examined for the presence of sea lice. We used a 3-point photographic scale to qualitatively categorize the severity of sea lice infestation (**Figure 1**) because the sea lice infecting grouper were too small to grossly quantify numerically (adults were between 2 and 4 mm) (**Figure 2**). The tissue reaction associated with the sea lice infections also obscured the parasites making it difficult to quantify (**Figure 1**). A fish was considered to have a category 1 level infection if there were three or fewer small (<1 cm) lesions with parasites in its oral cavity. A fish was considered to have a category 2 infection if there were more than three small lesions, or if the lesions in its oral cavity were larger than 1 cm in diameter.

FIGURE 2 | Photo of sea lice found on hybrid grouper during our study period.

Once a farm was confirmed to only have sea lice infections and no comorbidities (i.e., other parasites and or bacterial infections), we prescribed SLICE® (Merck & Co., Inc., Kenilworth, NJ, USA.) (0.2% EB) at the dose recommended for salmon: 50 μg EB/kg for 7 days. We monitored one pen of treated fish and one pen of untreated fish on each farm included in our study. The control fish (untreated) were usually from the same pen and were maintained in a small enclosure close to the treated animals. The number of fish in the treated pens across five farms ranged between 750 and 1,350, and the weight of the fish included in our study ranged from 0.2 to 2 kg depending on the farm. The untreated pens contained between 30 and 100 fish. The treated fish on each farm were only compared to the control fish on the same farm to control for exposure level. After 21 days post treatment, we offered to treat all control animals with EB.

We calculated the inclusion rate of the medication in the feed based on a 1% feeding rate, the number of fish being treated, and their weight. The EB medication (SLICE®) was hand-mixed in the existing commercial pelleted feed used by the farmer and top coated with canola oil. The veterinarians involved in the study mixed the 1st day of medication with the farmer to demonstrate the procedure. Farmers were asked to keep records of fish mortality in the treated and control fish groups. Water temperature and salinity were recorded on the days of fish sampling.

We randomly sampled five treated fish and five untreated fish on the 7th day of the treatment, and on days 14 and 21. All fish were collected using a dip net (outside of their regular feeding time). We used feed pellets to attract the fish population to the surface to collect our sample. We photographed the oral cavity of all fish and ranked their infection based on a 3-point scale (**Figure 1**). We calculated the proportion of treated and untreated fish with light infections (category 1) and with moderate to severe (category 2) infections at each sampling time point. Due to limited amount of fish with moderate infections (i.e., there were only 49 category two fish out of 189 fish sampled from five farms), we dichotomized the infection data (combined category 1 and 2) to statistically compare whether the proportions of fish with any infections differed between treated and untreated groups at different time points separately. We assessed whether these proportions differed significantly using a mixed effect logistic regression model with treatment as the fixed effect, and farm as the random effect. All analyses were conducted in STATA 15.0 (Stata Corp LLC, College Station TX USA).

Emamectin Benzoate (EB) Concentration Test

Muscle and skin tissues were collected from the same fish sampled for sea lice assessment on days 0, 7, and 21, on four out of the five farms[1] for EB analysis using liquid chromatography with tandem mass spectrometry (LC-MS-MS) as described in Lehotay (16). The samples were submitted frozen at -80^0C to a commercial laboratory (Chemical Testing Services, Faculty of Science, Hong Kong Baptist University, Hong Kong) for analysis. On the days when we sampled for LC-MS-MS we euthanized the fish with an Ikigun (Auckland, New Zealand). Tissue samples were frozen at −20°C and tested for EB at the end of the study. On the two last farms included in this study, we also sampled five treated fish on day 28 after the start of the treatment for EB tissue concentration in case the residue period was longer than expected. We graphically illustrate the EB tissue concentration in treated fish over time.

RESULTS

Water temperature during the treatments on the five study sites ranged from a minimum of 19.7°C to a maximum of 29.1°C (**Figure 3**). Salinity was always above 30‰ on three farms (#2, 4, and 5) and fluctuated between 21 and 32‰ on the other two sites (#1 and 3) (**Figure 3**). Only fish farms with confirmed sea lice infections in the oral cavity and no other pathogens on our initial health check were included in our trial. Farmers did not report any fish mortality during the trial period.

[1]One farm (farm 2) did not want us to conduct lethal sampling, so we did not submit samples for LC-MS-MS evaluation.

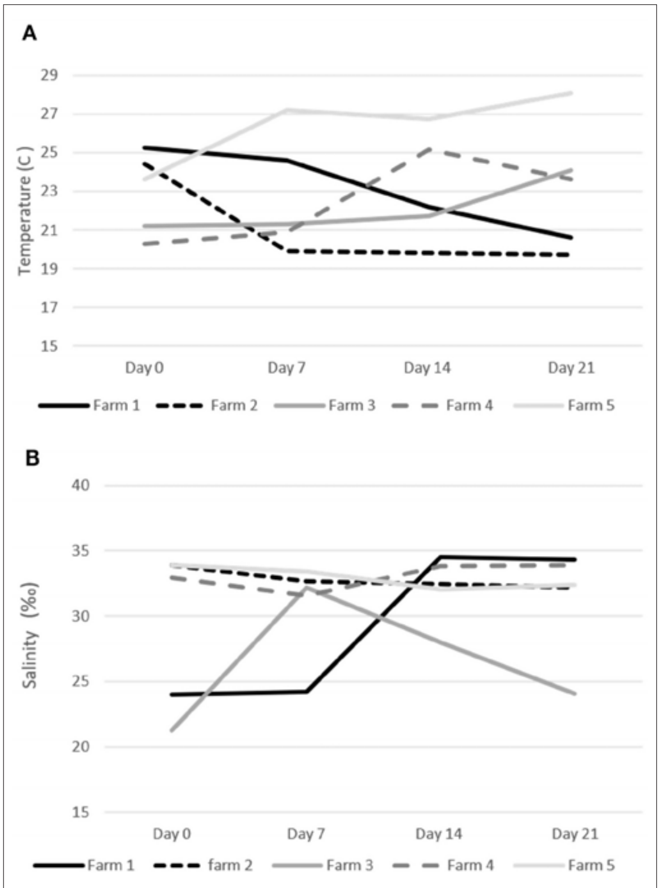

FIGURE 3 | Water temperature (C) and salinity (‰) during the emamectin benzoate sea lice trails. **(A)** Water temperature on specific farms. **(B)** Water salinity on specific farms.

The proportion of EB treated fish with parasites declined over time on all 5 farms (**Figure 4**). All fish sampled on farms had some level of infection with sea lice prior to starting the treatment. Twenty–one days into the trial the proportion of infected fish on farms that had received SLICE®, with the exception of the fish on farm 3, was below 40%. Two farms (farm 1 and 2) also had a decline in the proportion of infected fish not treated with EB (**Figure 4**). There were some treated groups that had better overall responses to the medication relative to their untreated counterparts (i.e., farms 1, 2, and 5; **Figure 4**). Overall, the proportion of fish infected with sea lice (category 1 and 2) was statistically lower in the treated groups of fish compared to the non-treated groups of fish, controlling for farm effect, on all days sampled (**Table 1**); however, the most significant difference was observed on the last day of sampling (day 21) (**Table 1**).

The concentration of EB in tissues was below the detectable limit of the LC-MS-MS analysis [2 parts per billion (ppb)] at the start of the trials, and in all fish not treated with SLICE® throughout the duration of the study, with the exception of one farm (#1) where the average EB concentration in the control fish

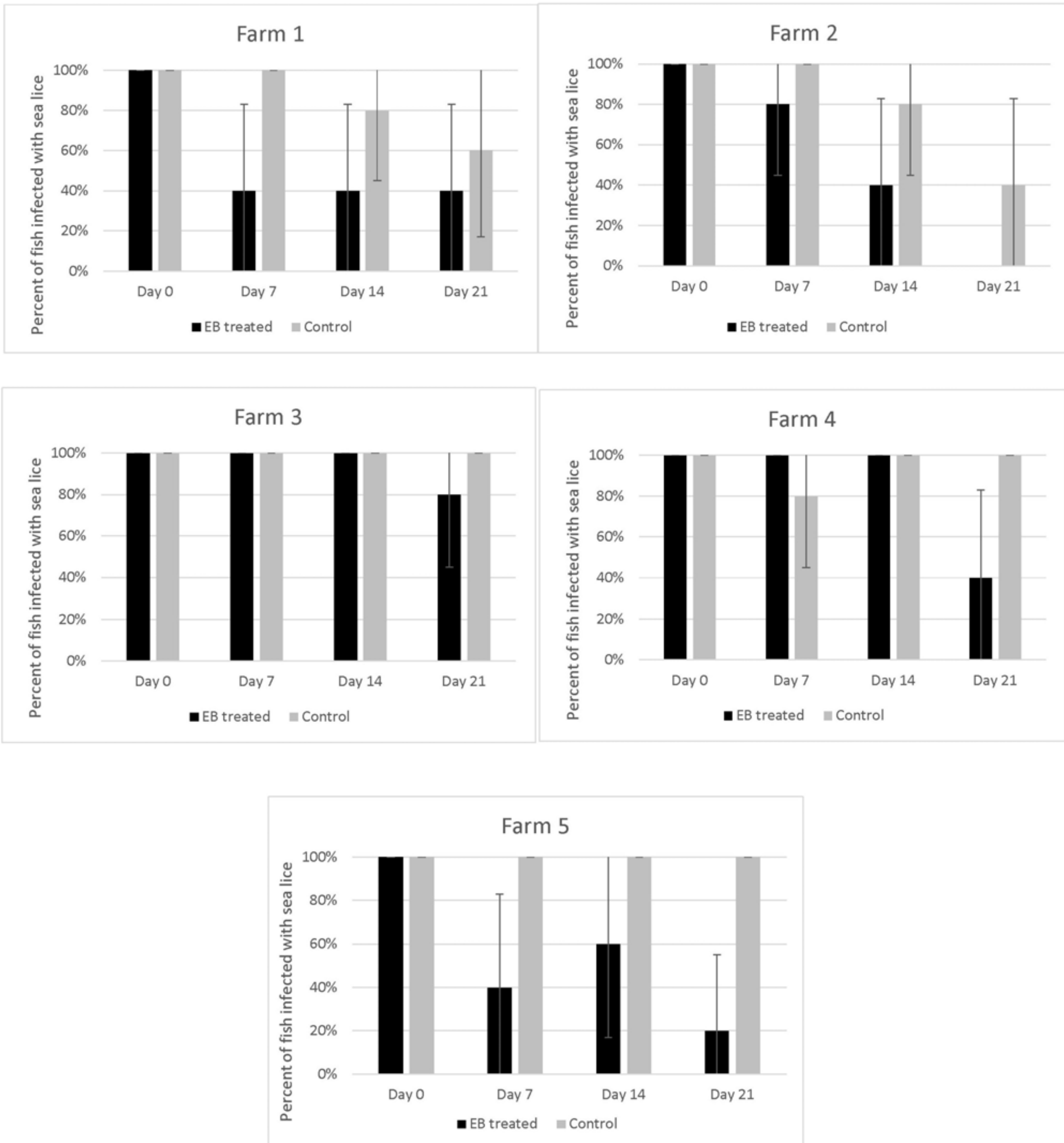

FIGURE 4 | Percentage of fish with sea lice infections on five different farms taking part in an emamectin benzoate trial. Five fish were collected from both untreated (control) and treated fish on the 1st day of treatment (Day 0), and subsequently on the last day of the treatment (Day 7), day 14 and 21 of the study. A fish was defined as infected if it had any evidence of sea lice in its oral cavity (category 1 or 2 on our photographic scale). Bars indicate 95% confidence intervals (+/- 1.96* $\sqrt{\frac{p*q}{n}}$).

on day 7 was 3.54 ppb (SE mean 0.578). There was a wide range of tissue concentrations on the last day of the treatment (day 7: <2 to 110.4 ppb). The range appeared to cluster by farms, with one farm appearing not to have any of its sampled fish with levels of EB above 2 parts per billion (mg/kg) (Farm #3) (**Figure 5**). All EB tissue concentrations were below 11 ppb in samples collected 21 days after the start of the first treatment or 14 days post treatment (**Figure 5**), and below 4 ppb (average 3.8, SE mean = 1.2) 21 days after the last treatment (i.e., 28 days from the start of the trials).

DISCUSSION

Our study identified an alternative treatment to bath chemotherapeutants for sea lice in hybrid grouper in Hong Kong. On the five farms in our study, the typical sea lice infections in hybrid grouper were reduced over time with the application of 7 days of SLICE®, a premixed product containing EB (12), at the recommended dose for salmonids (50 µg/kg/per day). The response to EB may take some time to occur as seen on farms 2 and 4 (**Figure 4**). Despite the fact that the level of EB in tissues of treated fish declined rapidly once the treatment ended (**Figure 5**) the effect of EB on the severity of infection continued to improve. This delayed response has been described in salmonids with *L. salmonis* and *C. rogercresseyi* (12), and is attributed to the mechanism of action of EB on the parasites' nervous system (12).

The response to treatment observed in this study varied by farm and was not as pronounced as what has been described in the early use of this product in the salmon industry (12, 17). Further, we observed sea lice in the oral cavity of several fish post-treatment (**Figure 4**), so we are confident that the EB treatment used did not completely eliminate the sea lice in all the treated fish.

Our inability to treat sea lice on grouper with 100% effectiveness (i.e., a small proportion of fish on all farms except one still had active sea lice infections after treatment) is likely due to several factors. First, the concentration of EB in fish was less than expected, given the dose we used. In fact, on one farm (Farm #3), the fish we sampled had negligible EB concentrations in their tissues on the last day of the treatment (**Figure 5**), suggesting a failed treatment. In salmonids, the same dose used in this study would result in a large proportion of fish with EB tissue concentrations above 60 parts per billion on the final day of the treatment (day 7) (18). The difference in the concentrations of EB in the fish from this study and salmonids may be multifactorial, and potentially played a role in the efficacy of the treatment. First, grouper and salmonids are different species cultured in very different water temperatures. The latter would have an impact on the metabolism of EB. Further, sea lice infections in grouper from Hong Kong occur in the oral cavity, which may impact the

TABLE 1 | Summary of mixed effect logistic regression models for day 7, 14, and 21 of our Emamectin benzoate trials.

Term	Coefficient	SE	*P*-value
DAY 7 MIXED EFFECT LOGISTIC REGRESSION MODEL			
Fixed effect			
Treatment	−2.286	1.137	0.044
Random effect			
Farm	0.216	0.785	0.3715
DAY 14 MIXED EFFECT LOGISTIC REGRESSION MODEL			
Fixed effect			
Treatment	−2.016	0.955	0.035
Random effect			
Farm	1.970	2.709	0.044
DAY 21 MIXED EFFECT LOGISTIC REGRESSION MODEL			
Fixed effect			
Treatment	−2.538	0.845	0.003
Random effect			
Farm	1.540	1.613	0.016

Farms were included as a random effect in the models. The comparison of the treatment was between control and treatment groups. Five fish were included in all samples with the exception of one sampling where two fish photographs were missing.

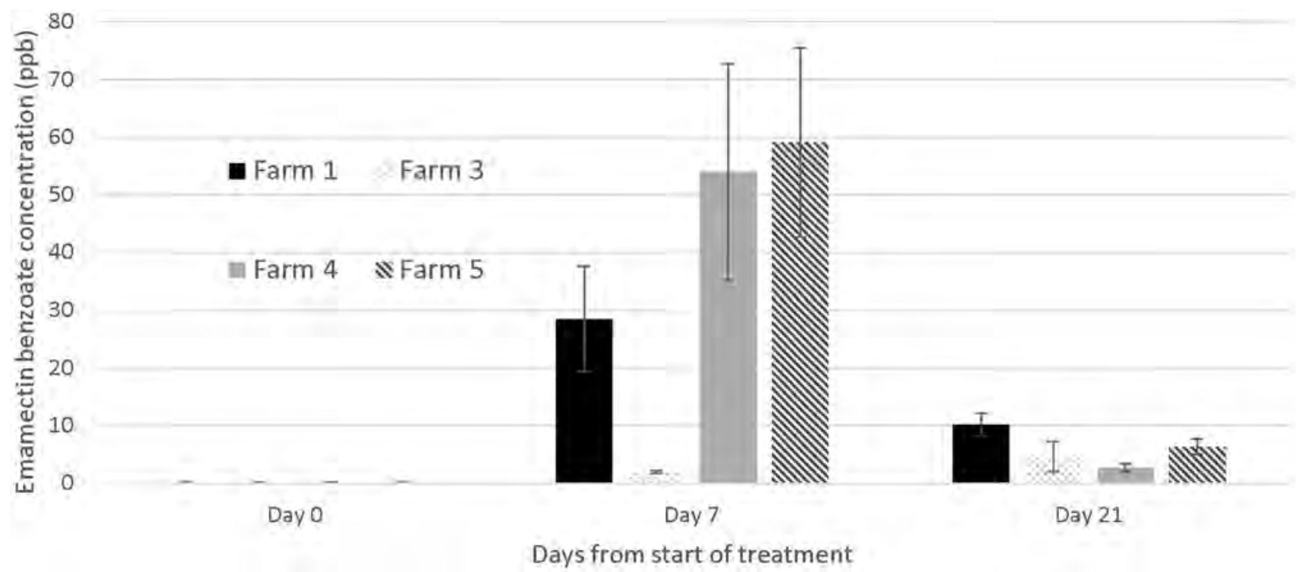

FIGURE 5 | Emamectin Benzoate concentration in muscle /skin samples collected from treated fish ($n = 5$) at different days during emamectin trials on four different farms. Emamectin is reported in parts per billion (ppb) and day 0 was the 1st day of treatment (prior to the administration of the first medicated feed). Bars indicate standard error for the mean EB tissue concentration.

amount of medication consumed by the fish. Our records suggest a large proportion of the fish on farm 3 had moderate to severe infections prior to the treatment (50% of the fish sampled on day 0 and 7 had category 2 infections on our photographic scale; data not shown), which may explain why there was virtually no EB in the tissues of all the fish sampled on farm 3. It is also possible that the concentration of medication was not evenly distributed in the feed and this resulted in a wide variation of doses to the fish. The EB LC-MS-MS data showed a wide range of tissue concentrations at the end of the treatment both within and between farms (**Figure 5**) with overall EMB concentrations ranging between not detectable to 110 μg/kg), suggesting that the medication may have been consumed unevenly by the fish or dispersed on the feed unevenly resulting in the same uneven dosing effect. The actual concentration of drug administered to the fish (50 μg/kg) relative to the amount of feed was very small, so it was challenging to obtain a homogeneous distribution on the feed. We tried to standardize the protocol by mixing the feed for the farmers, but the size and the oil content of the pellets used on different farms varied and may have impacted the distribution of the medication on the feed during the hand mixing process. In the salmonid industry, all EB treatments would be incorporated into the feed at the feed mills, so the concentration of the medication delivered to the fish would be more consistent.

It should be noted that our sampling of fish may have biased our estimates of EB concentration in fish. We had to hand net fish for our samples, so we may have collected fish that were not feeding and easier to catch at the surface, rather than the healthy population of fish that typically swim deeper in the water column and are more difficult to dip net. We did throw feed in the net-pens to try to reduce this bias, but we noted that the fish swimming rapidly in the net-pen were difficult to catch. Because we potentially sampled fish that did not feed as much as others, we may have underestimated the EB concentration in the population. This underestimation could explain some of the variation on EB concentration in tissue. Further, we only sampled five fish at each time point due to financial constraints. As participants in our study were small farms and infected fish were always over 1 kg with the exception of farm 1, it was cost prohibitive to sample more fish at each time point. This fact limited the accuracy of our population estimates.

In addition to influencing our estimate of EB in fish, our sampling strategy may also have biased our estimate of sea lice on fish. This bias would have occurred in both the control and treated fish groups, and it may have biased our results toward the null (under estimation of the effect). Despite the potential sampling bias, which is inherent in field trials on small farms, all farmers in our trial agreed (personal communication) that the treatment improved grouper feeding response and were pleased with the product, despite the persistence of the mild sea lice infections in the oral cavity of some fish (**Figure 5**). In fact, we only had mild infection (**Figure 1**) in fish 1-week post treatment (day 14) except on farm 3, which still had severe infections after the EB treatment. Farm 3 was also the farm where fish had limited EB in their tissues even on the last day of treatment.

Another explanation for the lower response rate to EB observed in this study, relative to the initial reports of the effect of EB on salmon lice, is that the lice are resistant to the product. Although we were not able to measure EB resistance in our study, this hypothesis is unlikely, given that to the best of our knowledge EB has not been used by the Hong Kong fish farming community. If farmers begin to use this product and are unable to properly mix the medicated feed to deliver an accurate therapeutic dose to their fish, they may observe resistance within a few years, as has been observed in many salmon farming areas around the world (7, 8, 15, 19). Having access to a local feed mill would help reduce the risk of uneven distribution of mediation within the feed and likely improve treatment delivery.

On two of the five participating farms we observed a natural decline in sea lice infections in the control fish (**Figure 4**). This may have been due to environmental factors such as water temperature and salinity, which are known to impact sea lice survival (20, 21). The salinity measures on farms were all above 30‰, with a few exceptions on two farms (**Figure 2**). On Farm 3 we observed a salinity of 21‰ but it is unlikely that this led to a natural reduction in sea lice levels as this was the farm with some of the most severe infections. Both farms (#1 and #2), which had a natural decline in sea lice infections over time, had high salinity. Although there may have been some medication drift on farm #1, as the LC-MS-MS data suggested minimal levels of EB in the control fish on day 7, this level was very low and unlikely to be therapeutic. More likely the reduction in sea lice in the control group on these farms was associated with a decline in water temperature. These two farms reported the lowest water temperatures of the study sites (**Figure 2**) and the decline in sea lice paralleled the decline in water temperature. The reproductive rate of sea lice in salmon industries has been shown to be temperature dependent (20–22). It is possible that water temperature had an influence on the reproduction of the sea lice in this study. Despite the potential natural decline in sea lice on farms 1 and 2, the effect of EB was still apparent in the treatment groups (**Figure 4**).

One of the limitations of this study was that unlike sea lice species found on salmon, which are easy to enumerate, the species in Hong Kong, are smaller (adults are estimated to be between 2 and 4 mm in length **Figure 2**) and cluster with various life stages inside the mouth of the fish, therefore they are more difficult to count (**Figure 1**). To address this issue, we used a three-point qualitative scale for categorizing the severity of infections and most infected fish in this study had mild infections. This qualitative scale limited our ability to assess the precise reduction in parasite numbers post-treatment. Despite this limitation in counting individual sea lice in the mouth of the fish, we were still able to measure changes in sea lice clusters and lesions.

Within 2 weeks of the last day of treatment, the level of EB in tissues was below 10 ppb. This decline in drug concentrations was steeper than what is reported in salmonids (11, 23–25), and was likely due to the elevated water temperature in our study (range between 19.7 and 29.1°C). By day 28 of our experiment

[21 days after the last treatment the average levels of EB were 3.8 ppb (SE = 1.14)], which suggests the withdrawal period of 21 days recommended for SLICE® at a dose of 50 μg EB/kg of fish per day for 7 days (12) could be used for grouper. The levels of EB in our fish tissue samples on day 21 were well below the 42 ppb maximum residue limit used in some countries (26).

In conclusion, EB appears to be effective for reducing sea lice in the oral cavity of hybrid grouper in Hong Kong. EB has potential to be used within the Asian grouper aquaculture industry with good results if protocols of administration are monitored closely. Response to treatment may be improved by refining the delivery of the product to fish and treating animals early in the infection process to ensure fish are still eating adequately to receive the proper dose of medication. Although we observed a decline in sea lice infestation on most farms after the use of SLICE®, a small percentage of treated fish still had parasites on all but one farm. The specific dose required for complete elimination of sea lice needs further investigation. This is important because exposing parasites to subtherapeutic levels of EB could exacerbate the risk that resistance develops to this therapeutant (27). Lastly, the environmental impact of using SLICE on farms in Asia should be assessed as it has recently been demonstrated to reduce the abundance of crustaceans in the benthic environment around salmon farms in Scotland (28).

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The animal study was reviewed and approved by City University of Hong Kong Ethics Committee. Written informed consent was obtained from the owners for the participation of their animals in this study.

AUTHOR CONTRIBUTIONS

SS-H was the project leader and wrote the first draft of the manuscript. TC, SC, KC, CL, and KL were the technical team who conducted the trails on the farms. WF was the graduate student who assisted with the writing of the manuscript and the data analysis. GBG assisted with the parasite identification and quantification. GBG contribute with article editing. All authors contributed to the article and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Appendix G

AMR Table (excel spreadsheet soft copy only)

Appendix G Summary of antibiotic sensitivity tests on fish pathogens between June 2018 and December 2020

Client ID	Geographical Region (culture zone for marine)	Bacterial species	Fish Species	Sampled tissue	Fresh or Salt water (+/-RAS)	Sample collection date	Erythromycin	Florfenicol	Gentamicin	Kanamycin	Lincomycin	Neomycin	Oxytetracycline	Penicillin	Spectinomycin	Oxolinic acid	Streptomycin	Tetracycline
13	Yuen Long	*Aeromonas hydrophila*	Jade Perch	Kidney	Fresh(RAS	01/08/19	I	S	S	S	R	S	R	R	S	R	S	NA
13	Yuen Long	*Aeromonas hydrophila*	Jade Perch	Eye	Fresh(RAS	01/08/19	I	R	S	R	R	S	R	R	S	R	S	NA
12	Hok Tau/Fanl	*Aeromonas spp*	Tilapia	Skin	Fresh	02/08/19	S	S	S	S	R	S	R	S	S	S	S	NA
13	Yuen Long	*Aeromonas spp*	Jade Perch	Kidney	Fresh(RAS	07/08/19	R	S	S	S	R	S	R	R	S	R	S	NA
13	Yuen Long	*Aeromonas spp*	Jade Perch	Skin	Fresh(RAS	08/08/19	I	S	I	I	R	I	S	R	S	R	R	NA
13	Yuen Long	*Aeromonas spp*	Jade Perch	Kidney	Fresh(RAS	08/08/19	S	S	S	I	R	S	S	R	S	R	R	NA
12	Hok Tau/Fanl	*Aeromonas spp*	Tilapia	Eye	Fresh	13/8/2019	R	S	S	S	R	S	S	S	S	S	S	NA
13	Yuen Long	*Aeromonas spp*	Jade Perch	Kidney	Fresh(RAS	26/8/2019	R	S	S	S	R	S	S	R	S	R	S	NA
22	Yuen Long	*Aeromonas spp*	Tilapia	Spleen	Fresh	27/9/2019	I	S	S	S	R	S	S	R	S	S	R	NA
13	Yuen Long	*Aeromonas hydrophila*	Jade Perch	Kidney	Fresh(RAS	15/4/2020	R	S	S	S	R	S	S	R	S	S	S	NA
13	Yuen Long	*Aeromonas hydrophila*	Jade Perch	Kidney	Fresh(RAS	27/4/2020	R	R	S	S	R	S	R	R	R	R	R	NA
13	Yuen Long	*Aeremonas hydrophila*	Jade Perch	Kidney	Fresh(RAS	14/5/2020	S	S	S	S	R	S	S	R	S	S	S	NA
33	San Tin	*Aeremonas jandaei*	Jade Perch	Kidney	Fresh	27/7/2020	R	S	I	R	R	I	S	R	S	S	R	NA
54	Ma Tso Lung	*Aeromonas hydrophila*	Grey Mulle	Ascitic fl	Fresh	29/7/2020	R	S	S	S	R	S	S	R	S	S	S	NA
54	Ma Tso Lung	*Aeromonas sp*	Grey Mulle	Kidney	Fresh	29/7/2020	R	R	S	S	R	S	I	R	S	S	S	NA
13	Yuen Long	*Aeromonas caviae complex*	Jade Perch	Kidney	Fresh(RAS	08/09/20	R	S	S	S	R	S	R	R	S	NA	NA	NA
62	Chai Wan	*Aeromonas hydrophila*	Jade Perch	kidney	Fresh(RAS	18/9/2020	R	S	S	S	R	NA	S	R	S	R	S	NA
62	Chai Wan	*Aeromonas jandaei*	Jade Perch	kidney	Fresh(RAS	18/9/2020	R	S	S	S	R	NA	S	R	S	R	S	NA
13	Yuen Long	*Aeromonas sp*	Jade Perch	Gills	Fresh(RAS	21/9/2020	NA	S	S	S	R	NA	S	R	S	R	I	NA
16	Mai Po	*Aeromonas sp*	Grey Mulle	Kidney	Fresh	30/9/2020	R	S	S	S	R	NA	S	R	S	R	S	NA
16	Mai Po	*Aeromomas hydrophila*	Grey Mulle	Kidney	Fresh	07/10/20	R	S	S	I	R	S	S	R	S	R	S	NA
16	Mai Po	*Aeromomas hydrophila*	Grey Mulle	Kidney	Fresh	07/10/20	I	S	S	S	R	S	S	R	S	S	R	NA
13	Yuen Long	*Aeromonas sp*	Jade Perch	Ascitic fl	Fresh(RAS	20/11/202	R	R	S	S	R	S	R	R	S	R	R	NA
13	Yuen Long	*Aeromonas sp*	Jade Perch	Kidney	Fresh(RAS	24/11/202	S	S	S	S	R	S	S	R	S	S	S	NA
13	Yuen Long	*Aeromonas sp*	Jade Perch	Kidney	Fresh(RAS	24/11/202	S	S	S	I	R	S	R	R	S	R	S	NA
13	Yuen Long	*Aeromonas sp*	Jade Perch	Eye	Fresh(RAS	24/11/202	S	S	S	S	R	S	R	R	S	R	S	NA
12	Hok Tau/Fanl	*Chryseobacterium spp*	Tilapia	Kidney	Fresh	02/08/19	S	S	R	R	R	S	S	R	S	S	I	NA
12	Hok Tau/Fanl	*Chryseobacterium spp*	Tilapia	Skin	Fresh	02/08/19	R	S	S	S	R	S	S	R	S	S	R	NA
12	Hok Tau/Fanl	*Edwardsiella tarda*	Tilapia	Eye	Fresh	13/8/2019	R	S	S	S	R	S	S	S	S	S	S	NA
13	Yuen Long	*Edwardsiella tarda*	Jade Perch	Kidney	Fresh(RAS	26/8/2019	R	R	S	S	R	S	R	R	S	S	R	NA
33	San Tin	*Edwardsiella tarda*	Jade Perch	Kidney	Fresh	27/7/2020	R	S	S	S	R	I	R	R	S	S	S	NA
16	Mai Po	*Edwardsiella tarda*	Grey Mulle	Kidney	Fresh	30/9/2020	I	S	S	S	R	NA	S	R	S	S	S	NA
11	Mai Po	*Enterobacter kobei*	Carp	Skin	Fresh	10/07/19	R	S	S	I	R	S	R	R	S	S	R	R
3	Yung Shue A	*Photobacterium damselae ssp damselae*	NA	Kidney	Salt	09/10/18	S	S	S	S	R	S	S	S	S	S	S	NA
5	Yim Tin Tsai	*Photobacterium damselae ssp piscida*	Hybrid Gro	Kidney	Salt	24/4/2019	R	S	S	I	R	S	R	R	S	S	R	NA
10	Yim Tin Tsai	*Photobacterium damselae ssp damselae*	Grouper	Flank (sk	Salt	27/6/2019	S	S	S	S	R	S	S	S	S	S	S	NA
6	Lau Fau Shai	*Photobacterium damselae ssp piscida*	Giant Grou	Kidney	Salt(RAS)	17/2/2020	S	R	S	I	R	S	R	R	S	S	R	NA
13	Yuen Long	*Plesiomonas spp*	Jade Perch	Kidney	Fresh(RAS	26/8/2019	I	R	S	R	R	S	R	R	S	R	R	NA
62	Chai Wan	*Plesiomonas shigelloides*	Jade Perch	Kidney	Fresh(RAS	18/9/2020	S	S	S	S	R	NA	S	R	S	S	I	NA
3	Yung Shue A	*Staphylococcus aureus*	Hybrid Gro	Skin	Salt	16/10/201	S	S	S	S	R	S	S	R	S	R	S	NA

Client ID	Geographical Region (culture zone for marine)	Bacterial species	Fish Species	Sampled tissue	Fresh or Salt water (+/-RAS)	Sample collection date	Erythromycin	Florfenicol	Gentamicin	Kanamycin	Lincomycin	Neomycin	Oxytetracycline	Penicillin	Spectinomycin	Oxolinic acid	Streptomycin	Tetracycline
3	Yung Shue A	*Streptococcus iniae*	Pompano	Kidney	Salt	05/10/18	R	S	S	R	S	R	S	S	S	R	R	NA
3	Yung Shue A	*Streptococcus iniae*	Pompano	Kidney	Salt	05/10/18	R	S	S	R	S	R	S	S	S	R	R	NA
3	Yung Shue A	*Streptococcus iniae*	Pompano	Kidney	Salt	05/10/18	R	S	S	R	R	R	S	S	S	R	R	NA
3	Yung Shue A	*Streptococcus iniae*	Pompano	Kidney	Salt	05/10/18	R	S	S	R	S	R	S	S	S	R	R	NA
6	Lau Fau Shai	*Vibrio vulnificus*	Giant Grou	Kidney	Salt(RAS)	19/9/2018	S	S	S	S	R	R	R	S	S	S	S	S
6	Lau Fau Shai	*Vibrio alginolyticus*	Giant Grou	Skin	Salt(RAS)	19/9/2018	S	S	S	S	R	R	R	R	S	R	S	R
2	Yim Tin Tsai	*Vibrio harveyi*	Pompano	Kidney	Salt	05/10/18	R	S	S	I	R	S	R	R	S	R	S	NA
3	Yung Shue A	*Vibrio harveyi*	Hybrid Gro	Skin	Salt	16/10/201	S	S	S	I	R	S	S	R	S	R	S	NA
3	Yung Shue A	*Vibrio harveyi*	Pompano	NA	Salt	30/10/201	I	S	S	S	R	S	S	R	S	R	R	NA
3	Yung Shue A	*Vibrio parahaemolyticus*	Pompano	NA	Salt	30/10/201	S	I	S	I	R	S	R	R	S	R	R	NA
3	Yung Shue A	*Vibrio alginolyticus*	Pompano	NA	Salt	30/10/201	I	I	S	I	R	S	R	R	S	R	R	NA
4	Lo Tik Wan (	*Vibrio harveyi*	Hybrid Gro	Kidney	Salt	20/11/201	S	S	S	S	R	S	R	R	S	R	S	NA
4	Lo Tik Wan (	*Vibrio harveyi*	Hybrid Gro	Kidney	Salt	20/11/201	S	S	S	S	R	S	R	R	S	R	S	NA
5	Yim Tin Tsai	*Vibrio harveyi*	Hybrid Gro	Kidney	Salt	29/11/201	R	S	S	R	R	S	R	R	S	R	S	NA
3	Yung Shue A	*Vibrio harveyi*	Pompano	NA	Salt	18/12/201	R	S	S	S	R	S	S	R	S	R	R	NA
3	Yung Shue A	*Vibrio harveyi*	Pompano	NA	Salt	18/12/201	I	S	S	I	R	S	S	R	S	R	I	NA
3	Yung Shue A	*Vibrio alginolyticus*	Pompano	NA	Salt	18/12/201	I	S	S	I	R	S	S	R	S	R	I	NA
7	Yim Tin Tsai	*Vibrio spp*	Hybrid Gro	Kidney	Salt	28/2/2019	R	S	S	S	R	S	S	R	S	R	R	NA
7	Yim Tin Tsai	*Vibrio harveyi*	Hybrid Gro	Kidney	Salt	05/03/19	S	NA	S	S	S	S	S	S	S	NA	S	NA
5	Yim Tin Tsai	*Vibrio harveyi*	Hybrid Gro	Kidney	Salt	12/04/19	S	NA	S	S	R	R	S	R	S	NA	S	S
5	Yim Tin Tsai	*Vibrio harveyi*	Hybrid Gro	Kidney	Salt	12/04/19	S	NA	S	R	R	R	S	R	S	NA	S	S
6	Lau Fau Shai	*Vibrio harveyi*	Giant Grou	Kidney	Salt(RAS)	15/4/2019	R	S	S	S	R	R	R	R	S	S	R	R
3	Yung Shue A	*Vibrio harveyi*	Pompano	Kidney	Salt	15/4/2019	S	S	S	S	R	R	S	R	S	S	S	S
3	Yung Shue A	*Vibrio spp*	Pompano	Kidney	Salt	29/4/2019	I	S	S	R	R	S	I	R	S	I	R	NA
3	Yung Shue A	*Vibrio harveyi*	Pompano	Kidney	Salt	29/4/2019	S	S	S	I	R	S	S	R	S	S	R	NA
3	Yung Shue A	*Vibrio harveyi*	Pompano	Kidney	Salt	07/05/19	S	S	S	R	R	S	S	S	S	S	R	NA
3	Yung Shue A	*Vibrio spp*	Pompano	Kidney	Salt	07/05/19	I	S	S	R	R	S	I	R	S	S	R	NA
3	Yung Shue A	*Vibrio harveyi*	Pompano	Kidney	Salt	03/06/19	S	S	S	I	R	S	R	R	S	R	I	NA
19	Tai Tau Chau	Vibrio spp	Grouper	Tail (Ski	Salt	21/6/2019	I	S	S	S	R	S	S	R	S	S	S	NA
19	Tai Tau Chau	*Vibrio alginolyticus*	Grouper	Kidney	Salt	21/6/2019	I	S	S	S	R	S	S	R	S	S	S	NA
6	Lau Fau Shai	*Vibrio vulnificus*	Giant Grou	Skin	Salt(RAS)	22/7/2019	R	R	S	I	R	S	R	R	S	I	R	NA
6	Lau Fau Shai	*Vibrio alginolyticus*	Giant Grou	Kidney	Salt(RAS)	22/7/2019	I	R	S	R	R	S	R	R	R	S	R	NA
6	Lau Fau Shai	*Vibrio vulnificus*	Giant Grou	Skin	Salt(RAS)	22/7/2019	R	S	S	I	R	S	R	S	S	S	R	NA
6	Lau Fau Shai	*Vibrio harveyi*	Giant Grou	Kidney	Salt(RAS)	17/2/2020	S	S	S	S	R	S	R	R	S	S	R	NA
6	Lau Fau Shai	*Vibrio vulnificus*	Giant Grou	Kidney	Salt(RAS)	17/2/2020	S	S	S	S	R	S	R	R	S	S	R	NA
19	Tai Tau Chau	*Vibrio alginolyticus*	Hybird Gro	Kidney	Salt	28/4/2020	R	S	S	S	R	S	S	R	S	S	S	NA
4	Lo Tik Wan (	*Vibrio harveyi*	Hybrid Gro	Kidney	Salt	31/7/2020	S	S	S	S	R	S	S	R	S	S	S	NA
6	Lau Fau Shai	*Vibrio vulnificus*	Giant Grou	Ascitic flu	Salt(RAS)	31/8/2020	R	S	S	I	R	I	S	S	S	S	S	NA
16	Mai Po	*Vibrio sp*	Grey Mulle	Kidney	Fresh	07/10/20	R	S	S	S	R	S	S	S	S	S	R	NA
4	Lo Tik Wan (	*Vibrio sp*	Giant Grou	Kidney	Salt	09/11/20	S	I	S	S	R	S	S	R	S	S	S	NA
4	Lo Tik Wan (	*Vibrio sp*	Giant Grou	Kidney	Salt	25/11/202	S	S	S	I	R	S	R	R	S	S	R	NA

Appendix H

Summer Grey Mullet Investigation

Appendix H

Report on the Investigation of Grey Mullet (*Mugil cephalus*) "Summer Mortality" in Hong Kong

City University of Hong Kong, Aquaculture Ambulatory Team

CONTENTS

SUMMARY

An investigation into factors that may contribute to summer mortality of grey mullet (*Mugil cephalus*) in Hong Kong was conducted on four ponds from two farms between late May and September of 2020. Farmers reported mortality events, and various water parameters and rainfall patterns were examined weekly. We also noted management events reported by the farmers on a weekly basis. Each pond was unique, but many of the mortality events were preceded by management events or a cyclone. How these events resulted in mortality is not fully known. In some cases, the events may have led to water quality issues; however, the frequency of monitoring in our study was not sufficient to confirm cause and effect. Also, different events may have led to different water quality issues and there were some underlying issues with water quality that likely exacerbated the events (i.e. stressed fish).
In brief, during some of our sampling periods we detected low Dissolved oxygen, low pH, high total ammonia, high nitrite, and high water temperatures. We also observed some indications of stratification in ponds, which could be problematic under certain weather conditions (i.e. hot calm weather followed by cyclones or heavy winds). Although our study did not precisely pinpoint the event(s) that lead to mortality, we identified several issues that may have, in combination, led to fish mortality. We recommend that farmers monitor their water quality, especially before and after changes in management or hot weather events, to mitigate issues early and minimize losses. Interestingly, we also detected low levels of *Streptococcus* spp. throughout the summer, suggesting that fish may be able to tolerate these bacteria at low levels without mass mortality, and that other underlying events may be required to initiate significant mortality losses associated with these pathogens.

1. INTRODUCTION

Grey mullet (*Mugil cephalus*) has been a prominent species in Hong Kong aquaculture for decades, and the species has been successfully reared by open pond aquaculture system over the years using traditional semi-intensive methods. Mortality in summer has contributed to severe loss of stocks among the local farms in recent years. Agriculture, Fish and Conservation Department (AFCD) recorded up to 80% losses during mortality events on some farms between 2010 and 2019. Since the induction of the City University Aquaculture Ambulatory service, we have observed severe mortality of *M. cephalus* on multiple farms in the New Territory area during the 2018 and 2019 summer and early autumn periods.

Mass mortality events were usually acute in nature, with most deceased fish lacking external symptoms, although a small percentage of fish had visible signs such as exophthalmos, as well as diffused inflammation on the fin and body. Based on AFCD's records, they isolated *Streptococcus iniae* from the internal organs (liver, spleen and kidney) of symptomatic fish in a few mortality cases, indicating systemic bacterial infections and raising speculations that the cause of summer mortality events were of bacterial origin. Records from AFCD also indicated that water quality (i.e. high water temperatures were associated with several fish kills) may have preceded bacterial outbreaks in aquaculture production systems. The purpose of this study was to investigate summer mortality on mullet farms to determine the predisposing factors.

2. MATERIALS AND METHODS

We informed our fish clients that we were interested in investigating fish mortality events and to call us early in the disease process to improve the outcome. Further, we conducted detailed water quality monitoring on two farms with a history of summer mortality events in the New Territories, Hong Kong.

2.1 Pond selection and pond profile

Four ponds on two separate farms were selected for this study, based on farmers' willingness to cooperate and the occurrence of previous events of *M. cephalus* mortality during the summer months. Table 1 summarises the profiles of the four ponds:

Pond	1	2	3	4
[1]Pond Size (square metre)	15010	15451	10083	7373
[1]Depth of Pond (metre)	1.7-2.3	1.8-2.5	1.3-3.0	1.1-2.6
[2]Fish species and population at the start of study	*Mugil cephalus*(20000) [3]*Ctenopharyngodon idella* (ua) [3]*Hypophthalmuchthys nobilis (*ua) [3]*Oreochromis spp* (ua)	*Mugil cephalus*(20000) *Ctenopharyngodon idella*(ua) *Hypopththalmichthys nobilis* (ua) *Oreochromis sp*(ua)	*Mugil cephalus* (25000) [3]*Scortum barcoo*(30000) *Oreochromis spp*(ua) ***	*Mugil cephalus (*20000) *Hypophthalmichthys nobilis (*2000) *Oreochromis spp (*3000) ** 2400 kg total biomass of stock addition on 17 June 2020 of above species and *Ctenopharyngodon idella*
[2]Stocking rate (kg/square metre)	0.6	0.58	2.7	10
[2]Stock date	March 2019	March 2019	June 2019	June 2019
[2]Feed used	**** By-products and commercially formulated pellets	By-products and commercially formulated pellets	Pellets (formulated by farmer)	Pellets (formulated by farmer)
[2]Amount of feed/day (kg)	240	240	400	120
[2]Last drained and dredged	2018	2018	May 2019	May 2019
*Number of Aerators	3	3 (2 more added on 9 Sep 2020)	5	1

Table 1. Stocking rate, species of fish, feeding practices and brief history of the four ponds included in the study

Notes:

1. Information on pond size was provided by AFCD; pond depths were obtained from measurement during study period.

2. Information on stocking rates, species, feeding and husbandry was verbally provided by farmers.
* With exceptions, usually only one aerator was switched on at a time, for 10-20 hours in total per day.
** Fish stock was increased in pond on mid-June 2020, harvest end of August 2020
*** Partial harvest early August 2020
**** By-products were processed human foods eg. bread, instant noodles
ua - population number unavailable
3. *Ctenopharyngodon idella* (Grass carp)
Hypophthalmuchthys nobilis (Big-head carp)
Oreochromis spp (Nile or hybrid tilapia)
Scortum barcoo (Jade perch)

2.2 Water sampling and analysis

Four water samples, two from the surface and two close to the bottom of the pond at the periphery and the center of the pond, were collected once per week for analysis. Samples were collected between 10 am and 12 pm, at approximately seven day intervals, from the last week of May 2020 until the third week of September, 2020. The 4 water sampling sites on each pond were kept consistent throughout the study.

The dissolved oxygen (DO), water temperature, pH, total ammonia nitrogen (TAN), nitrite, carbonate hardness (KH), Secchi disc readings for the deep samples, and depth of pond were measured using a HACH SL1000 PPA system, a pH probe PHC20101 (for TAN, nitrite, KH, pH), a smart Sensor pH 818 pH meter (from May to Mid-August 2020), and a YSI Professional Optical Dissolved Oxygen (YSI ODO). Water samples were diluted five times before using the HACH kit, due to the low detection range of TAN for this system and the high levels in our ponds. Deep water samples from the centre of ponds were also sent to a HOKLAS (Hong Kong Laboratory Accreditation Scheme) accredited laboratory for heterotrophic bacterial plate count (HPC) and faecal *Streptococci* counts (FSC).

2.3 Records of events and recommendations to farmers during the investigation period

Husbandry changes, harvests, mortality, and morbidity events on the day of, or in the week preceding our visit and water sampling were recorded. These were based on the farm hand or farm owners observations. Whenever we detected unfavourable water quality parameters that might adversely affect fish health the farmers were informed and advised on corrective measures, to prevent or minimise fish mortality.

2.4 Weather records

Weather conditions and barometric pressure readings from the YSI were noted on sampling days. Rainfall data (i.e. cumulative seven-day rainfall preceding the visit) was extracted from the Hong Kong Observatory Website. A seven-day cumulative rainfall preceding each data collection day was calculated for each pond and plotted with various parameters and estimated mortality

3. RESULTS

We did not have any fish clients that called with mass mortality events in their mullet ponds during our study period so no investigations were performed. The following are the results of our intensive water quality surveillance on two farms.

3.1 Mortality, water quality, and events

Chronic low-grade mortality was detected across all four ponds, with the earliest detectable mortality in Pond 2 on July 6, 2020. Daily mortality rates were not recorded accurately, but were recorded based on anecdotal reports from the farm operators. In general, mortality was reported to be was less than 0.1% (around 10 fish per day). There were a few larger mortality events (between 30 and 40 fish per day) throughout the summer. The mortality and husbandry events are summarised in Table 2a (for Farm 1, Pond 1 and 2) and Table 2b (for Farm 2, Pond 3 and 4):

Table 2a. Mortality and events in Pond 1 and 2 (information obtained verbally from farmers and approximate cursory counts)

Date	Pond 1	Pond 2
22 June	***Pond fertilisation***	***Pond fertilisation***
6 July	Receiving water from Pond 2	M2* *Mugil cephalus* and *Hypophthalamuchthys nobilis*; water pumped into from pond 1
13 July	-	M2 *Mugil cephalus* and *Hypophthalamuchthys nobilis*
20 July	-	M2 *Mugil cephalus* and *Hypophthalamuchthys nobilis*
27 July	M1 *Mugil cephalus*	M1 *Mugil cephalus*
3 August	M1 *Mugil cephalus*	M1 *Mugil cephalus*
10 August	M1 *Mugil cephalus*	M2 *Mugil cephalus*
17 August	M2 *Mugil cephalus*	-
19 August	***Tropical cyclone***	***Tropical cyclone***
24 August	M3 reported by farmer (no mention of species)	M3 various species
31 August	-	M2 various species
7 September	M2 *Mugil cephalus*	M3 mainly *Hypophthalamuchthys nobilis*, ***2 extra aerators added***
14 September	-	M3 mainly *Hypophthalamuchthys nobilis*
21 September	-	M1 various species, three aerators switched on

Table 2b. Mortality and events in Pond 3 and 4 (information obtained verbally from farmers and approximate cursory counts)

Date	Pond 3	Pond 4
3 to 10 Jun	-	Farmer reported poor appetite in fish, water change (low pH detected)
17 June	-	***2400 kg biomass of fish of various species added post-harvest, water pumped in***
24 June	-	M4 *Oreochromis sp*
30 June	***Added lime past week, Increase feed rate***	***Added lime past week, Increase feed rate***
8 July	***Partial harvest***	-

15 July	***Increase feed rate***	***Increase feed rate***
29 July	M3 *Mugil cephalus and Oreochromis sp*	M2 *Mugil cephalus, Hypophthalamuchthys nobilis* and *Oreochromis sp*
5 Aug	M1 *Mugil cephalus*	M1 *Mugil cephalus*
12 August	M1 *Mugil cephalus*	M1 *Mugil cephalus*
19 August	***Tropical cyclone***	***Tropical cyclone***
26 August	-	M3 *Hypophthalamuchthys nobilis.* ***Post-harvest, stop production cycle***
2 September	--	M3 *Hypophthalamuchthys nobilis*. Stop production
8 September	-	M2 *Hypophthalamuchthys nobilis*
23 September	M1 *Mugil cephalus*	M1 various species

Notes for table 2a and 2b:
*Arbitrary mortality grade:
M1 (very minor fish mortality, <10 fish)
M2 (minor fish mortality, 10 to 30 fish)
M3 (moderate fish mortality, 30 to 40 fish)
M4 (moderate to significant fish mortality, >40)
Bold and Italics – notable events

Mortality patterns differed between ponds, with Ponds 2 and 4 experiencing more mortality events, from June to September, whereas the mortality cluster of Pond 1 occurred in August (section 3.2 and 3.3). Pond 3 experienced mortality spikes in late July (corresponding to increased feeding rate) and mid-August, in association with a cyclone. The cyclone was associated with an increase in mortality in all pens. Pen 4 also had an increase in mortality associated with increased feeding rates.

Deceased fish reportedly exhibited minimal to no external symptoms, which is typical of acute mortality associated with water quality issues. Fish carcasses were usually bloated in appearance in various degree of decomposition (likely deceased for more than 24-36 hours before gas distension caused carcasses to float). No live fish or fresh dead fish were available for postmortem or sampling.

A brief episode of poor appetite (3-10 June) reported in Pond 4 corresponded with low pH, but these signs resolved with liming of the ponds. **Almost all increases in mortality can be explained by events such as over stocking, over feeding, or tropical cyclones (fig 1).**

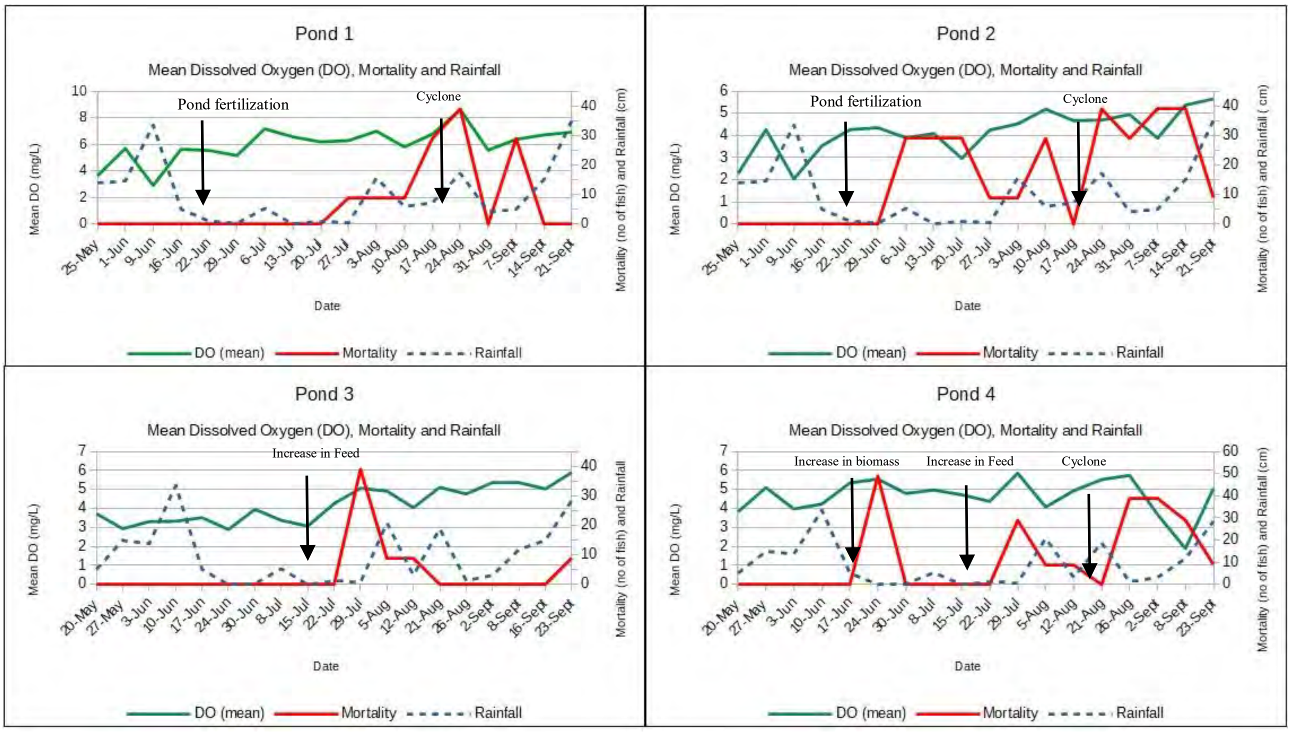

Figure 1. Mortality, events, Oxygen and rainfall in four ponds.

Water Quality

3.2 Water quality and events

Mean water parameter values for the surface and deep samples for each pond were calculated weekly and graphed with mortality and rainfall (see section 3.3 for details on rainfall). Dissolved oxygen (DO), pH, total ammonia nitrogen (TAN), and unionized ammonia (UIA) were compared directly across four ponds. Weather events, fish mortality, and rainfall were plotted with various parameters to determine correlations.

Pond 1 appeared to have a higher mean DO (6.03mg/L) than the other three ponds (4.16 mg/L, 4.21 mg/L, 4.65 mg/L for Pond 2, 3 and 4 respectively) (fig. 2). DO gradually increased in Ponds 1, 2, and 3, while it decreased in Pond 4 over the course of the study. On three occasions the DO at 10 am was below 2 mg/L and the DO was only above 7 mg/L in one pond once. It is possible that the DO in ponds at certain times of the year was lower at sunrise as there were reports of heavy algal growth in some ponds.

Overall comment: Although DO may have been low on some days, as we measured it at 10 am, it did not seem low enough to result in mortality. Pond 4 may have been an exception. In this pond in mid-August the DO appeared to crash and they also reported relatively high mortality.

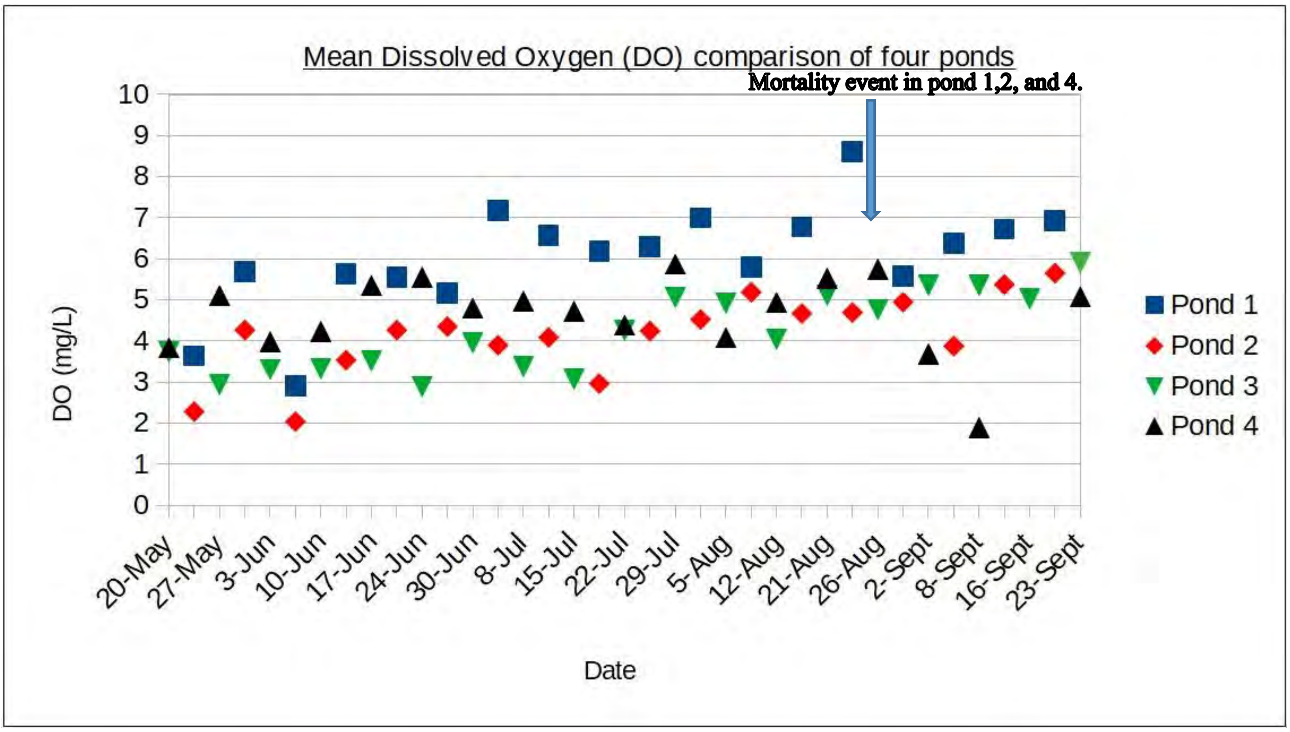

Figure 2. Mean Dissolved Oxygen (DO) comparison of four ponds

Water *temperature* in all ponds rose to over 30°C after mid-June, and this high water temperature was largely sustained until early September, with dips below 30°C in early to mid-August (3 August in Ponds 1 and 2, 5 August in Ponds 3 and 4) (Fig 3). The optimal temperature range for mullet is between 20 and 26°C. Mullet may be able to tolerate these temperatures if the water temperature is increased slowly, but the fish may still be stressed by these high water temperatures, especially if other water quality parameters are not optimal. It was difficult to interpret the interactions between water temperature and other water quality parameters in this study.

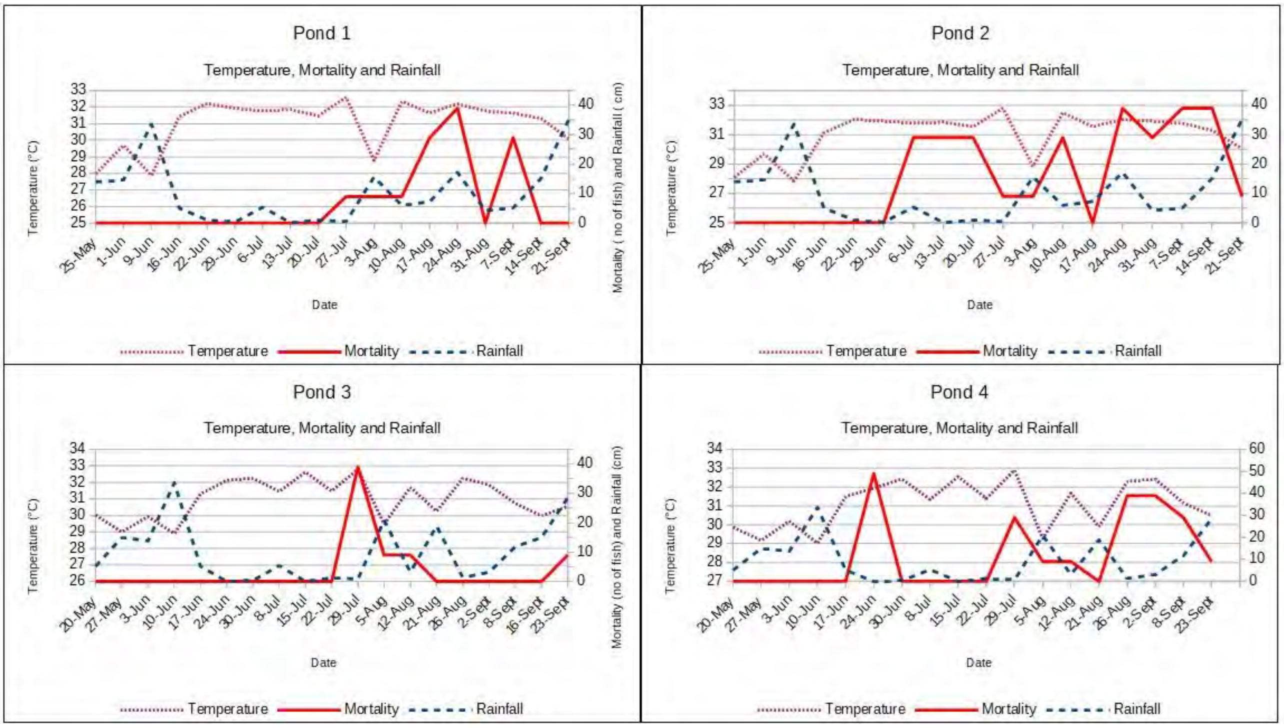

Figure 3. Water temperature, mortality, and rainfall in ponds 1,2,3,and 4.

The mean *pH* throughout the study period for Ponds 1, 2, 3, and 4 were 7.93, 7.75, 6.56, and 6.39 respectively (Fig. 4). The pH was stable in Ponds 1 and 2, falling within the range of 7 to 8.5. The pH of Ponds 3 and 4 tended toward acidity (< 6.9), with a sharp dip to nearly 5 in Pond 4 in mid-June. The farmer added lime on June 30th to stabilize the system. There was no correlation between pH and mortality or rainfall (fig.4).

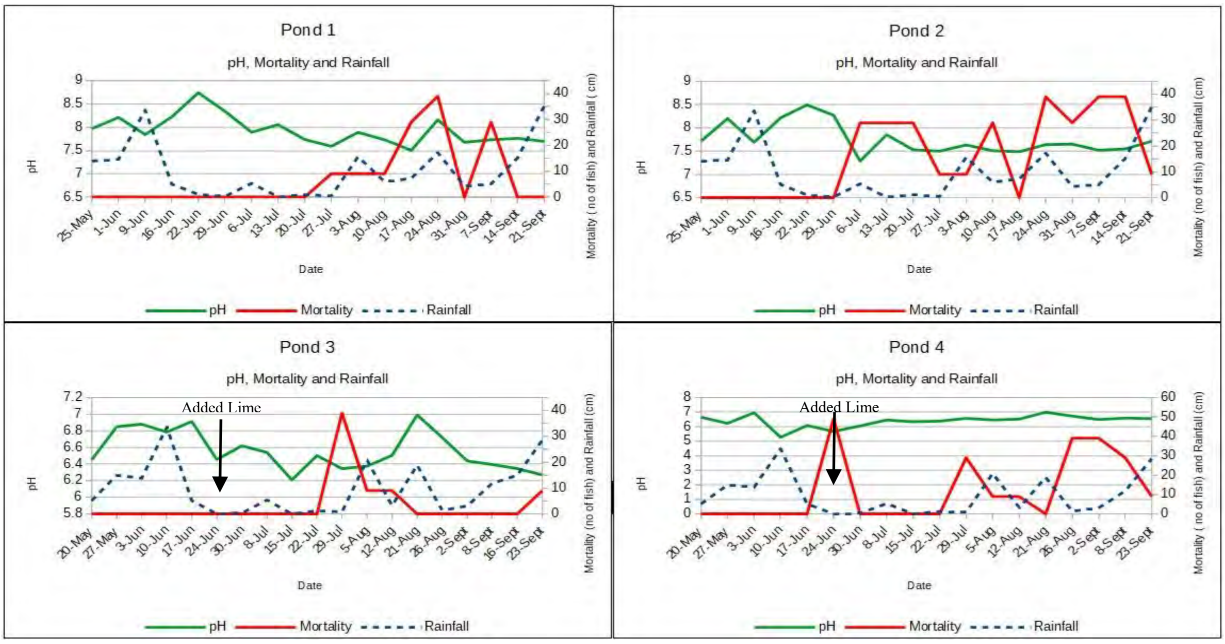

Figure 4. The pH, mortality and rainfall comparisons in four ponds

It is important to recognize that measuring pH once per day does not provide a clear picture of the potential daily fluctuation that can happen with this parameter, and which can stress fish. We ran

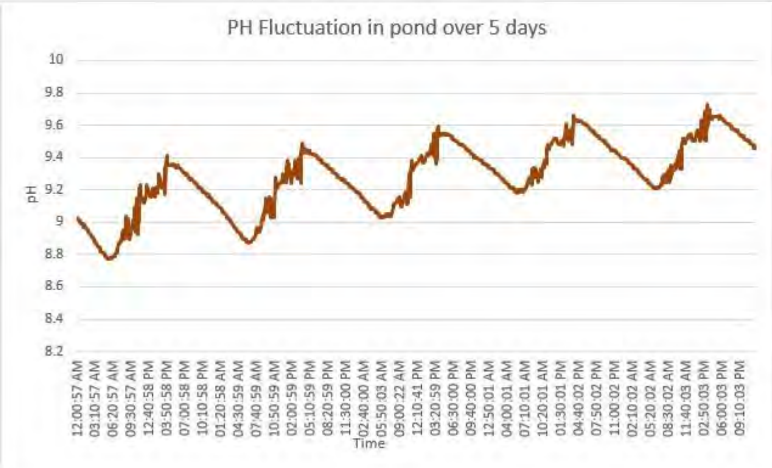

Figure 5. pH over a 5 day interval at Au Tau Fisheries .

a probe at a different site, which measured pH continuously, and which highlights the issue that can occur when pond water is not well buffered and algal growth is high (i.e. high CO_2 at night drives the pH down) (Fig5).

Water hardness is important for buffering the pH of ponds. In our study, the ponds with the lowest pH at 10 am were the ponds with the lowest KH (Fig. 6). The farmer of ponds 3 and 4 limed the ponds to improve the buffering capacity and increase the pH on June 30th. This management appeared to have a slight effect on the KH two weeks after but the pH did not change significantly, especially in pond 3. It is important that mitigative strategies are monitored to ensure they are effective.

Total ammonia nitrogen (TAN) in Ponds 1 and 2 were between 0.8 to 1.8 mg/L, respectively. Ponds 3 and 4 had higher TAN, which hovered largely between 2 to 3 mg/L and peaked at 5 mg/L in both

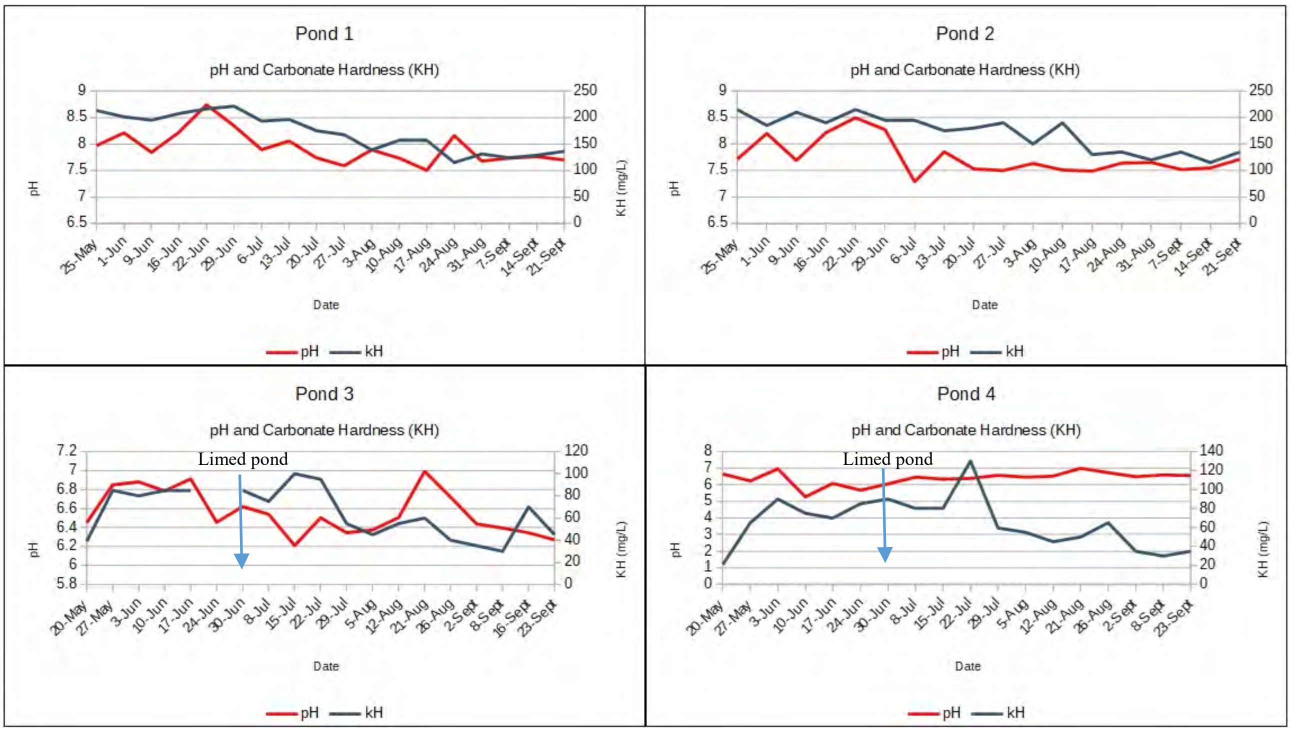

Figure 6. KH and pH over time in four ponds.

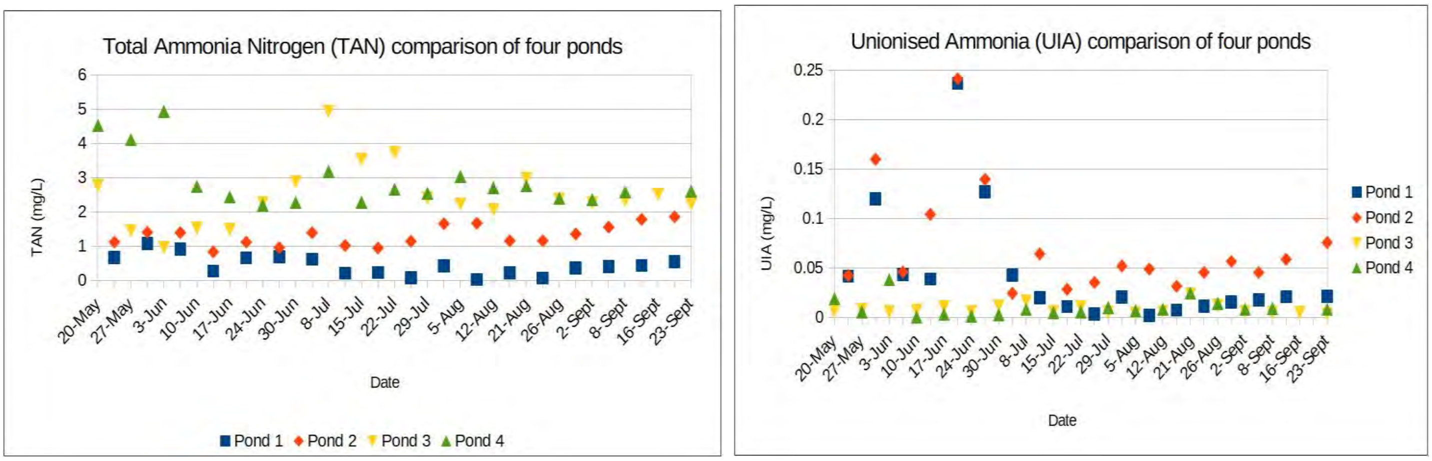

Figure 7. Total ammonia nitrogen and unionized ammonia in study ponds over time.

ponds (Fig. 7). However, because the pH in ponds 3 and 4 was low, the unionized ammonia in these ponds was much lower than in ponds 1 and 2 (Fig. 8).

Unionized ammonia (UIA) was above 0.05mg/L (toxic level for some species) in May and early July in Ponds 1 and 2, and in Pond 2, UIA was sustained at 0.05 mg/L for the entire study (Fig.9). UIA never exceeded 0.05 mg/L (toxic levels) in Ponds 3 and 4 (Fig. 7). The start of the sustained, low-grade mortality in Pond 2 occurred two weeks after UIA peaked, and continued throughout the course of the study. This pond also had high mortality after July; however, several other events coincided with the mortality spikes. Pond 1 also had increase in mortality during the study, but did not have associated mortality when UIA was high in June; mortality only started in August, in fact, after the UIA decreased. There was a positive correlation between mortality and UIA in Ponds 3 and 4, but UIA in those ponds did not exceed toxic levels and thus, any correlation was unlikely meaningful.

The *nitrite* levels were very low in Pond 1 (< 0.1 mg/L) and Pond 2 (< 0.14 mg/L). However, in Ponds 3 and 4, earlier months saw nitrite rise to 1.2 mg/L in Pond 3 and > 2 mg/L in Pond 4 (Fig. 10). Nitrite in Pond 3 remained above 0.2 mg/L throughout the study period. Whether this was correlated with mortality is unknown, but biologically it could add a stressor for the fish.

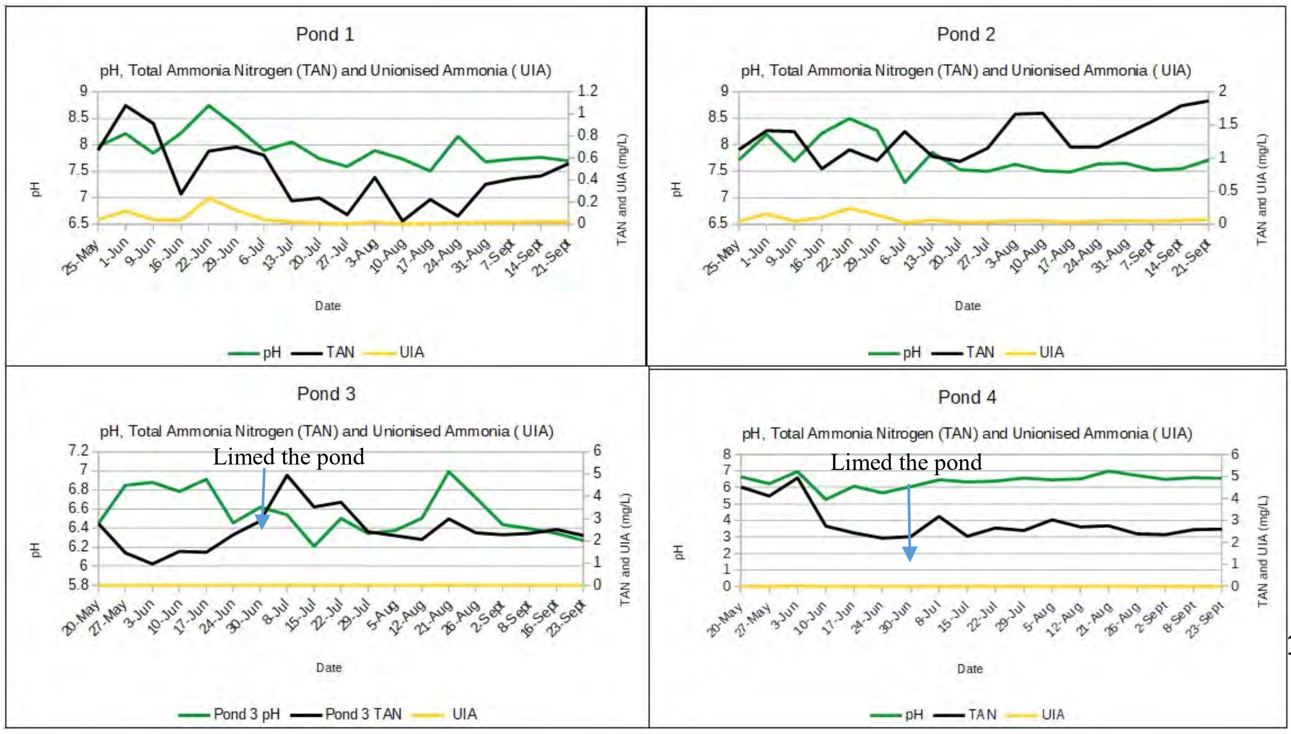

Figure 8. TAN, pH, and unionized ammonia in four ponds.

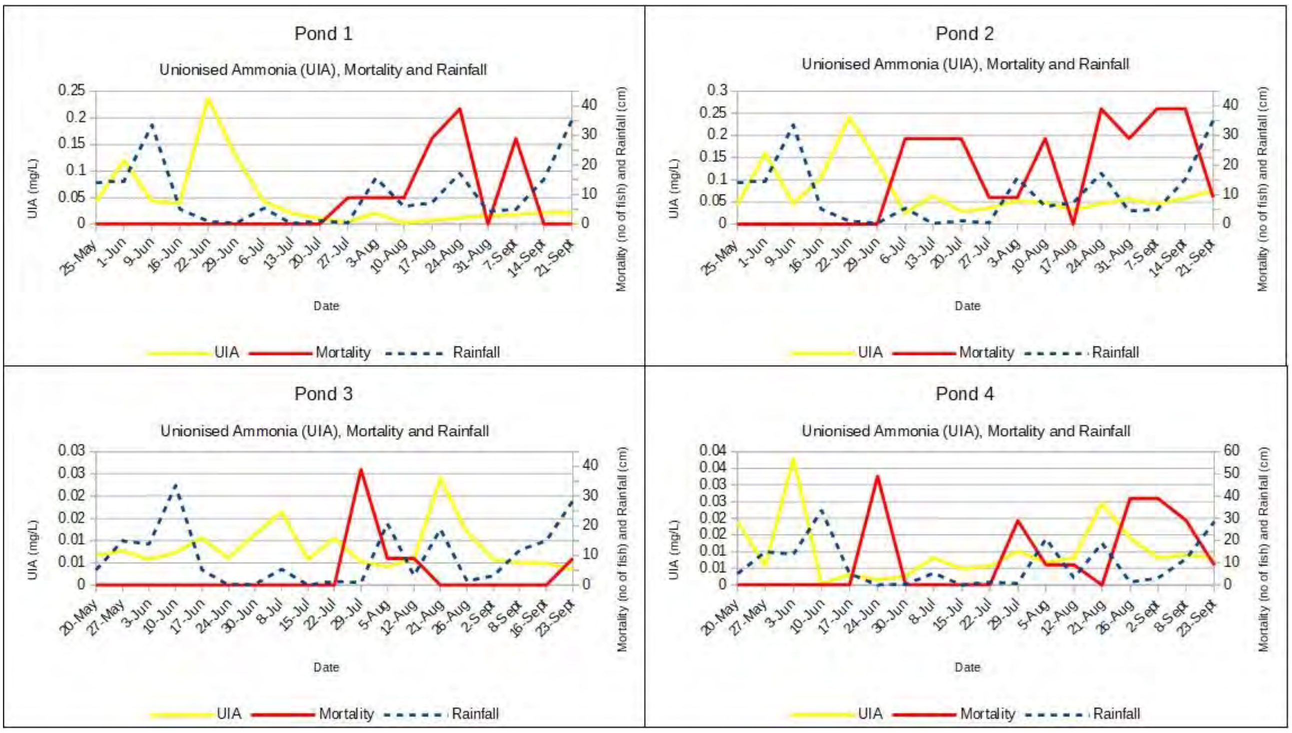

Figure 9. Correlations between Total Ammonia Nitrogen (TAN), Mortality and Rainfall of the four ponds

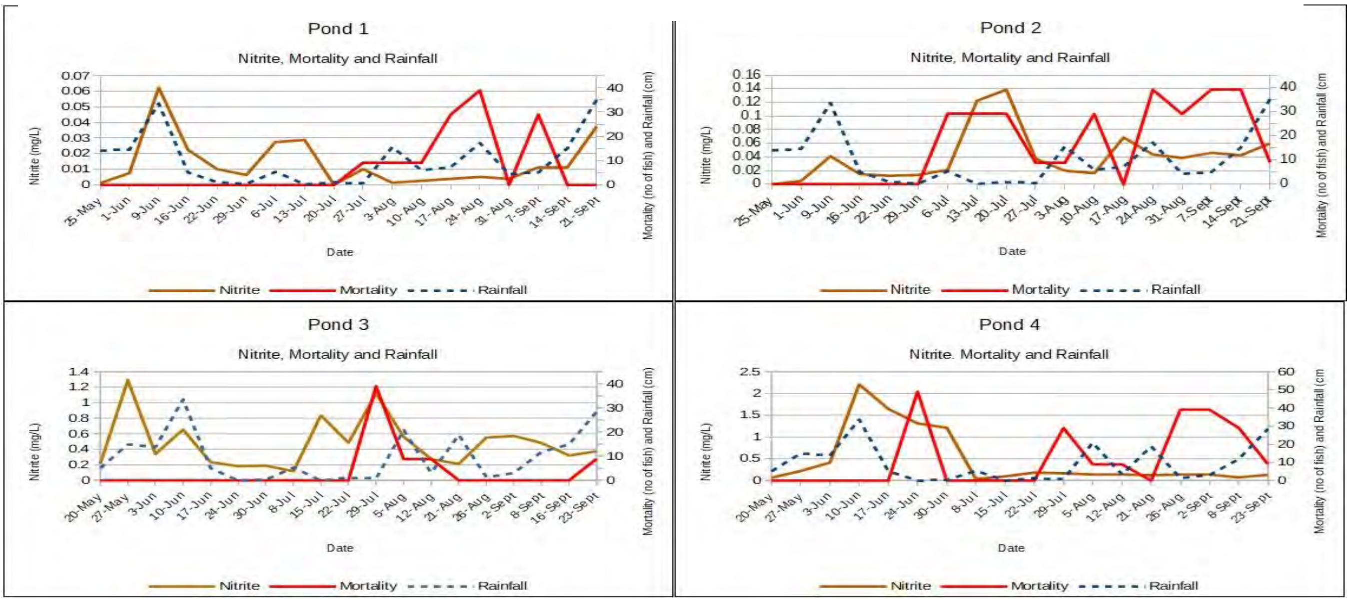

Figure 10. *Nitrite, Mortality and Rainfall of the four ponds of the four ponds*

There were *heterotrophic plate count (HPC)* peaks in the earlier months of the study for Ponds 1 (May and June), 2 (June and July), and 4 (early June). These coincided with pond fertilization in Ponds 1 and 2 and an introduction of biomass in Pond 4. Pond 4 also experienced a small peak near the end of July after increasing feeding. For Pond 3, there was a peak in mid-July associated with increased feeding (Fig. 11). The HPC peaks appeared to precede mortality in Ponds 3 and 4 by two weeks. In Pond 2, the initial HPC peak preceded the mortality peak by two weeks, and then another, subsequent peak coincided with a period of sustained mortality; but when HPC declined, eventually, mortality continued to persist. It is possible that increasing HPC is a direct result of events such as pond fertilization, increase feeding, and increasing the biomass, which subsequently resulted in fish mortality.

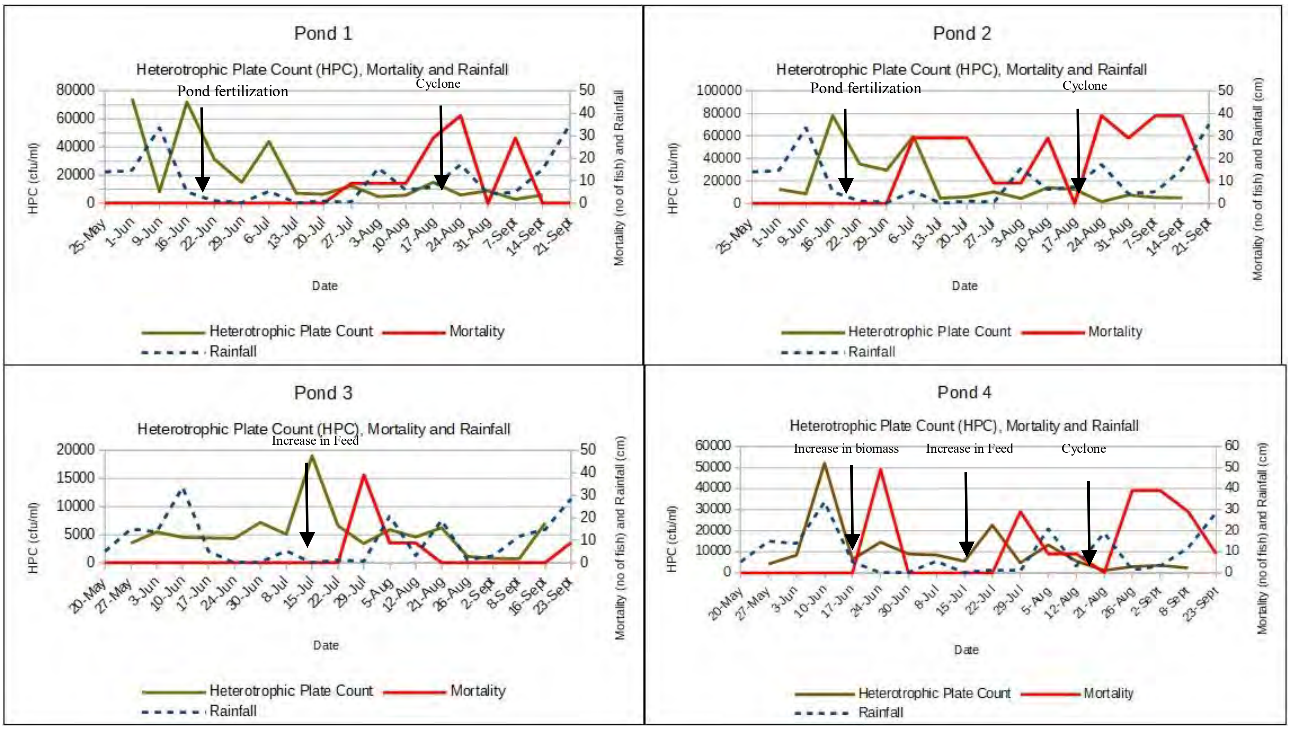

Figure 11. Heterotrophic Plate Count (HPC), Mortality and Rainfall of the four ponds

Faecal Streptococci count (FSC) was relatively high in Ponds 1 (>1000 cfu/ml) and 2 (>1000 cfu/ml) at the start of the study (Fig. 12). Interestingly, the fecal count went down after fertilization in these two ponds. The FSC in Pond 4 was also high (i.e. > 200 cfu/ml) at the start of the study, but subsequently fluctuated at levels below 50 cfu/ml. FSC was generally low in Pond 3 throughout the study (< 35 cfu/ml). These findings suggest that *Streptococcus* is present in the ponds without

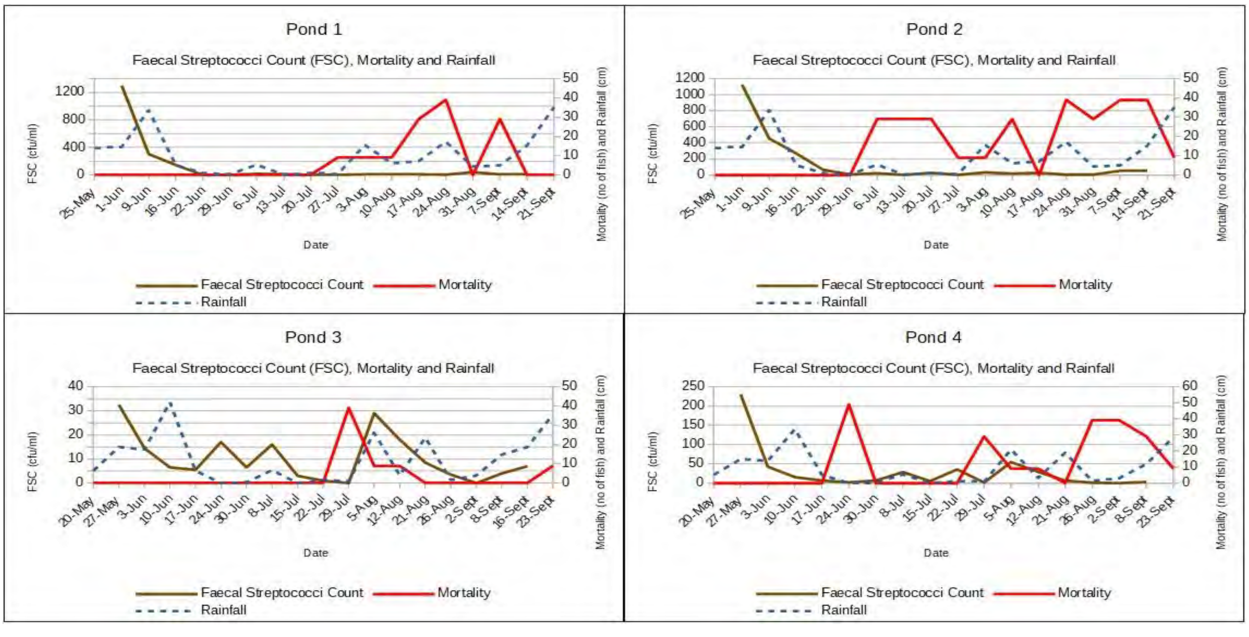

Figure 12. Streptococcus spp. counts in different ponds.

significant mortality. It also suggests that the spikes in HPC were not necessarily *Streptococcus,* which could explain why they may not have corresponded to high fish mortalities.

3.2 Weather and rainfall in relation to mortality and water parameters

Overall, rainfall levels were markedly lower than in the previous two years (2018/2019). There was a peak of rainfall at the end of June followed by a dry July, and steadier rainfall which started in August (see figures in section 3.2).

The rainfall and temperature in 2020 differed significantly from the historical norms for the month of July. Hong Kong Observatory noted in their monthly summary that "July 2020 was the hottest month in Hong Kong since record keeping began in 1884," with a long spell of sunny weather. The month was also much drier than usual. The total monthly rainfall was only 125.4 millimetres, about 33 percent of the normal figure of 376.5 millimetres. The accumulated rainfall for the first seven months of the year was 1088.8 millimetres, about 26 percent below the normal figure of 1473.3 millimetres.

Even for the month of June, it was noted by the Hong Kong Observatory that “despite the heavy rain episode on 6-8 June, the monthly total rainfall was only 397.2 millimetres, about 13 percent below the normal figure of 456.1 millimetres. The accumulated rainfall for the first half of the year of 963.4 millimetres was about 12 percent below the normal figure of 1096.9 millimetres."

There was a negative correlation between rainfall and *temperature* (Fig. 3). In July, when there was sparse rain, the temperature rose above 31°C and more or less persisted at that level until mid-early August. Rain returned in August, with a drop in temperature.

Stratification of the water column can occur in ponds when there is a long period of warm weather without any wind or rain to mix the surface and bottom water layers. When there is a wind event, the water layers in the pond can be suddenly turned over and cause water quality issues (i.e. low DO). In our study, we evaluated water quality in the centre of the pond at different levels to assess whether this stratification of water occurred (Fig. 13). There was some evidence that deep water samples had lower DO than the surface samples. We did not measure wind in this study, which may explain some of the mixing of the water and convergence of the DO on some dates. It is also possible that the farmers ran the aerators more aggressively during the day to prevent stratification on very hot days. We were unable to detect a difference between the temperature of water in the deep and surface samples, so if stratification occurred it was minimal in our study.

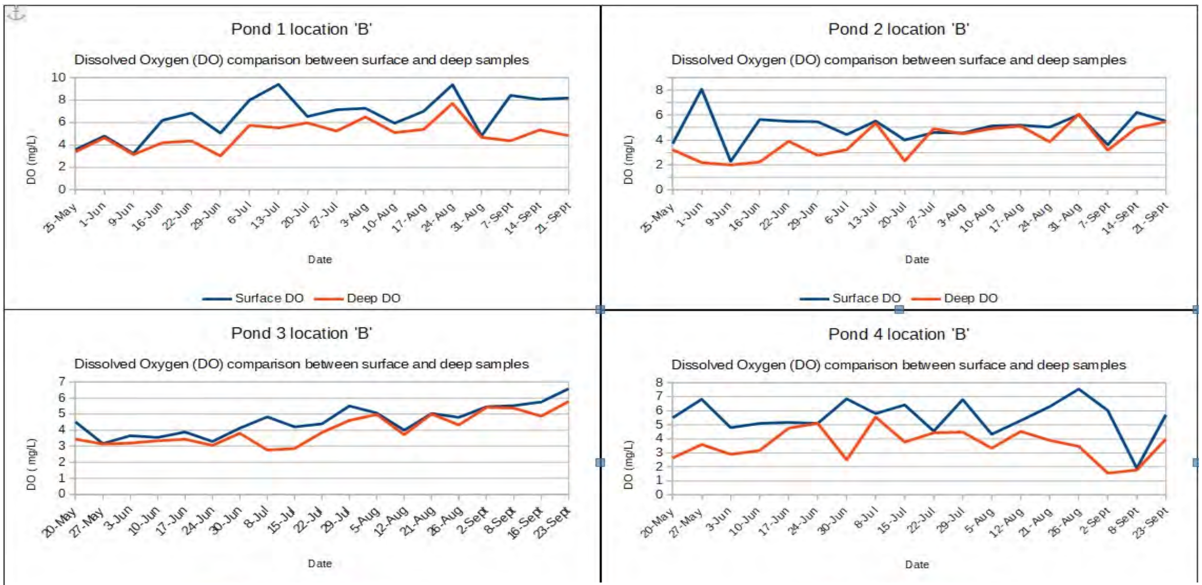

Figure 13. Dissolved Oxygen at surface and deep samples collected in the centre of the ponds

4. DISCUSSION

4.1 Mortality correlation with various water parameters and events

Based on farmers' reports, mortality in earthen ponds in the summer of 2020 were not as high as reported in previous years. Despite this, farmers still reported a few episodes of elevated morality and, in general, these events were preceded by activities such as fertilization of ponds, increased feeding of fish, increasing the stocking density, and tropical cyclones (Fig. 1). The mechanism by which these events may have led to mortality was likely a change in water quality, but we were not able to precisely measure this with our sampling strategy. Many of the events should have led to increased bacterial levels, and /or a drop in oxygen or change in ammonia, but this was not clear from our weekly water quality data. We did observe some problematic water quality parameters during our sampling, but they were not always associated with fish mortality.

Several issues with water quality were identified during our study that could be problematic for mullet health. First, the high water temperature in the summer likely stressed fish as it was always at least 4 to 6 degrees Celsius above the optimal level for mullet. Second, t*otal ammonia nitrogen (TAN)* was often high. Based on our pH reading, the unionized component of the ammonia was not high (high pH) but fluctuations in pH could not be determined in our study because we only surveyed ponds between 10 and 12 am on a weekly basis. The lowest pH would occur earlier in the day when the algae were using cellular respiration and producing CO2. We did observe a large fluctuation in pH in a similar pond at a different site which had a continuous monitoring probe. The lowest pH water was in the two ponds with the lowest buffering capacity (ponds 4 and 5 Fig. 6). A 24-hour probe is ideal for monitoring the diurnal rise and fall of pH, temperature and DO due to presence of sunlight and algal activity.

We cannot for certain conclude that nitrite led to fish mortality in this study, but suffice to say that nitrite levels were at the toxic level in at least one pond (#4). With concurrent unfavourable conditions, nitrite can be toxic at 1 mg/L. Long-term (over 6 months) exposure to even very low nitrite levels (0.015 – 0.060 mg/L) can result in mild methemoglobinemia in some fish; this was not observed in fish in our ponds but it was difficult to assess dead fish in this study.

Dissolved oxygen (DO) level is a prime consideration in any aquaculture system. Many factors affect DO – biological oxygen demand (BOD) from biomass (stocking rate) and bacteria population, zooplankton and phytoplankton bloom and die-offs, algal photosynthesis, and temperature. Dissolved oxygen in our study sometimes dipped too low for optimal mullet health and because we did not measure DO before sunset it may have been lower than what we reported in this study.

We observed a slight stratification in the ponds with lower DO in the deeper water. AFCD records have suggested a correlation between severe mortality in *M. cephalus* and high rainfall during the summers. Summer fish kills are often attributed to the phenomenon of pond turnover. Over the course of the summer, large amounts of organic matter can accumulate in the deeper areas of stratified ponds. Premature mixing of these stratified layers can occur after a period of very warm weather followed by sudden heavy rains. Oxygen-deficient bottom layers mix with upper layers, resulting in critically low oxygen levels throughout the water column, resulting in possible acute mass fish mortality. Sediments may also release unfavourable toxic compounds such as hydrogen sulphide into the water column. In summers with higher temperature, demand for oxygen in a pond ecosystem is higher than would be in colder months, accentuating the ill-effects of such events. Heavy rain events can also flush chemicals into the water from the soil of banks and surrounding land, exacerbating the negative impact of rain.

Interestingly, S*treptococcus* spp. were detected in all ponds in this study but were not associated with high levels of mortality, suggesting the identification of streptococcus in the water at low concentrations does not necessarily warrant antibiotic treatment and that this pathogen is ubiquitous in the area. It is possible that if fish are stressed the *Streptococcus* spp. could infect the fish and initiate a fish kill, as has been reported in the past. Maintaining low stress environments may be the key to preventing streptococcus infections. In most reported increases in mortality in this study, there was an event that preceded the mortality.

We suspect the causes of low-and medium grade mortality in this study were multi-factorial, and each pond has its own unique issues. Factors such as expanding biomass, sudden increase in feeding, high water temperatures, fluctuating pH, pond turnover after the cyclone, and or water temperatures over the tolerable limits for *M. cephalus* had negative impacts on fish health. These factors are frequently encountered in semi-intensive open pond aquaculture in Hong Kong.

4.2 The influence of market pressures on pond management and water parameters

Fish productions and sales heavily influence production management and, in turn, influence feeding strategies within a production cycle. Sales in Hong Kong for *M. cephalus* (and other fish species) usually peak around autumn to meet demands for fish products during certain festivals (Mid-Autumn festival, National holiday, Chong Yeung Festival). Therefore, farms will intensify production to target maximal fish growth between July and early September. The increased feeding and stock additions to target this market during the hottest period of the year can affect water parameters. Thus, it is not surprising that this stage of the production cycle, which coincides with unstable summer weather and fluctuating temperatures and rainfall, could trigger massive mortality, especially when conditions for a pond turnover are present. This is especially so if ponds are not closely monitored, or no extra mitigating measures are taken to offset the increased production demands.

4.3 Limitations of the study

There were information gaps in this study. As mentioned, we did not have good farm records and therefore, feeding rates, stocking densities, daily mortality rate, chemical usage, water exchange, and the aerator(s) operational time and placement variation could only be estimated. This lack of precision made it impossible to conduct statistical trend analyses on these farms and may have biased our findings. Another limitation was that there were large variations between the study ponds in terms of size, shape, and stocking density, making it difficult to compare ponds. Lastly, mitigating measures carried out by the farmers upon our advice, when we detected unfavourable conditions (i.e. increase aeration or water exchange), might have, to some degree, altered pond water characteristics and masked the factors which resulted in major grey mullet mortality events in previous summers.

5. Conclusions and recommendations

Although there were no massive fish kills in the ponds that we monitored over the summer of 2020 there were some water quality issues identified and management strategies that likely caused some mortality in *M. cephalus*. The following are recommendations to reduce the impact of some of these events on fish mortality.

1) When adding fish (biomass) to a pond:
    a. ensure the water quality can support the increase in biomass and the additional feeding that occurs with the increased biomass
    b. Ensure fish introduced to the pond are healthy so pathogens are not introduced into the system
2) When increasing feeding:
    a. Ensure it is done in a gradual manner so the water quality is not compromised
    b. Ensure the ammonia in the pond is not too high
    c. Ensure the DO in the pond can support the extra ammonia produced by the increased feed rate
3) To reduce the potential for pond turn-over during a cyclone:
    a. Aerate the pond when the weather is very hot and there is no wind, to reduce the likelihood of stratification
4) Fluctuations in DO and pH:
    a. Reduce the algae by changing the water, copper treatment, apply nanobubbles, adding algae-eating fish, reduce the sunlight to the pond
    b. Increase the buffering capacity of the pond by increasing KH, but only if the TAN is not too high (otherwise TAN will shift to more toxic form of ammonia).
        i. Prepare the ponds before fish enter to make sure the bottom is not anoxic and the soil is well buffered (limed)
5) To increase the DO:
    a. If the problem is only in the early morning,
        i. Control the algae (see 4.a.)
    b. If the problem is throughout the day
        i. Increase the algae
        ii. Increase the aeration in the pond, especially in the evening. To avoid stratification, aerate during the hottest part of the day
6) To reduce ammonia:

a. Reduce feeding
b. Increase heterotrophic bacteria
c. Increase algae
d. Reduce stocking density
e. Change water
f. Clean the ponds periodically to reduce organic material on the bottom

7) To reduce nitrite:
   a. Change the salinity of the water (add salt water if avaible. Chloride competitively inhibits uptake of nitrite through the gills)
   b. Increase nitrification bacteria
   c. Reduce feeding

Appendix I

Outreach events

Appendix H

From: [redacted]
To: Prof. Sophie ST-HILAIRE
Cc: [redacted]
Subject: Re: Flyer for farmers
Date: Tuesday, 2 October 2018 6:56:04 AM
Attachments: Flyer.pdf

Hi Prof Sophie, please see attached flyer . Hope this help and thank you for the support.

Best regards

[redacted]

On Monday, October 1, 2018 1:58 PM, Prof. Sophie ST-HILAIRE <ssthilai@cityu.edu.hk> wrote:

HI [redacted]

Thanks for this.

I will print some copies off for the talks but can you send me a one pager (with a photo and a few words plus your logo info) that I can translate and send to the aquaculture association on Tues. I want to get the farmers to come to your presentation… I don't think they will read 8 pages until after they have heard your talk!

Cheers,

Sophie

From: [redacted]
Sent: Monday, 1 October 2018 1:27 PM
To: Prof. Sophie ST-HILAIRE <ssthilai@cityu.edu.hk>
Subject: Re: Flyer for farmers

Hi Prof Sophie , please find attached flyer and brochure for shrimp farm.
please feel free to comments

Best regards

[redacted]

On Monday, October 1, 2018 12:09:32 PM +08, [redacted] wrote:

Hi prof sophie , the arrange looks good. i will revert by this evening on the material.

Best regards

[redacted]

Sent from Yahoo Mail on Android

On Mon, 1 Oct 2018 at 9:42, Prof. Sophie ST-HILAIRE <ssthilai@cityu.edu.hk> wrote:

Hi James

Can you design this flyer for the farmers here in HK for Friday. Sorry about the short notice I just really thought of this idea over the weekend given I could not find a farm to take you to! I will try to recruit as many farmers as I can to come and hear what nanobubble technology can do for aquaculture. I would focus your presentation on where it is applied already with some personal experiences in Indonesia…you can also mention that we are working to test different applications with you but I would not promise them that it will get rid of all their diseases yet!!

Do you speak Cantonese? If so it would be better to do the presentation in Cantonese but if not I will have my technician translate That means the talk will be a bit slower! . If you can make your slides in Chinese that is best but if not please send us the slides before thurs and we can translate some of them.   I would put more pictures than words on them… they are easier to translate!!

I will set up the meeting from 10 to 11 am on Friday.

Sophie

香港城市大學
City University of Hong Kong
Cornell University

Jockey Club
College of Veterinary Medicine
and Life Sciences
in collaboration with Cornell University

Prof Sophie St-Hilaire
DVM, MSc, PhD, MBA

Professor

Department of Infectious Diseases and Public Health

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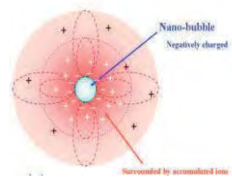
Kowloon, Hong Kong
Tel: (852) 3442 5398
Fax: (852) 3442 0589
Website: www.cityu.edu.hk/ph

NanoBubble Technology & Farming

1) Stay in the water for long time. Micro-organism can be activated due to the oxygen inside these bubbles



2) It has Negative charge that can attract positive molecules and enable the bubble to stay in the water for long time

3) When it Collapse it decomposed Organic Foulants and produce OH Radicals

Benefits

Water Quality Management

NB can increased the DO of the pond and maintain stable pH throughout. Hence, reduced used of paddle wheel resulted in energy saving

NB can reduced NH3 and NO2 hence minimised water changed energy saving

NB can exterminate bacteria due to free radical effect

Disease Outbreak

NB will minimized disease outbreak

Low Survival rate

NB will increased Survival rate to 90%.

Model : aQua+110M

Description	Specification
Dimensions	635 (W) X 300 (D) X 400 (H) mm
Weight	Approx. 30Kg
Inlet/Outlet connector	32mm(1 1/8") /25 mm (1') Dia
Power Supply	Single phase* 220V*50HZ
Power consumption	1.5hp (1.1KW)
Principle of Bubble Generation	Pressurized Dissolutions Method (PDM)
Water temperature	5 to 60 deg C
Bubble Size	50nm – 250nm (80%)
Water type	Fresh Water n Marine water
Auto BackWash With Self recovery	Yes
Output*	4.0 m3/hr

Jockey Club College of Veterinary Medicine and Life Sciences
香港城市大學
City University of Hong Kong
in collaboration with Cornell University

水產養殖業工作坊
如何在水產養殖中謹慎使用抗生素

了解怎樣及何時使用抗生素來降低魚類的死亡率。
如何在飼料中混合抗生素以及如何監測魚類對這些產品的反應，以提高治療的成功率。

日期: 2019年6月5日(星期三)
時間: 下午1:30至4:30
地點: 元朗屏山孖峰嶺香港農業聯合會辦事處

**如有興趣，請於6月2日前致電或whatsapp(電話:5596-0777)，以便安排坐位。謝謝!

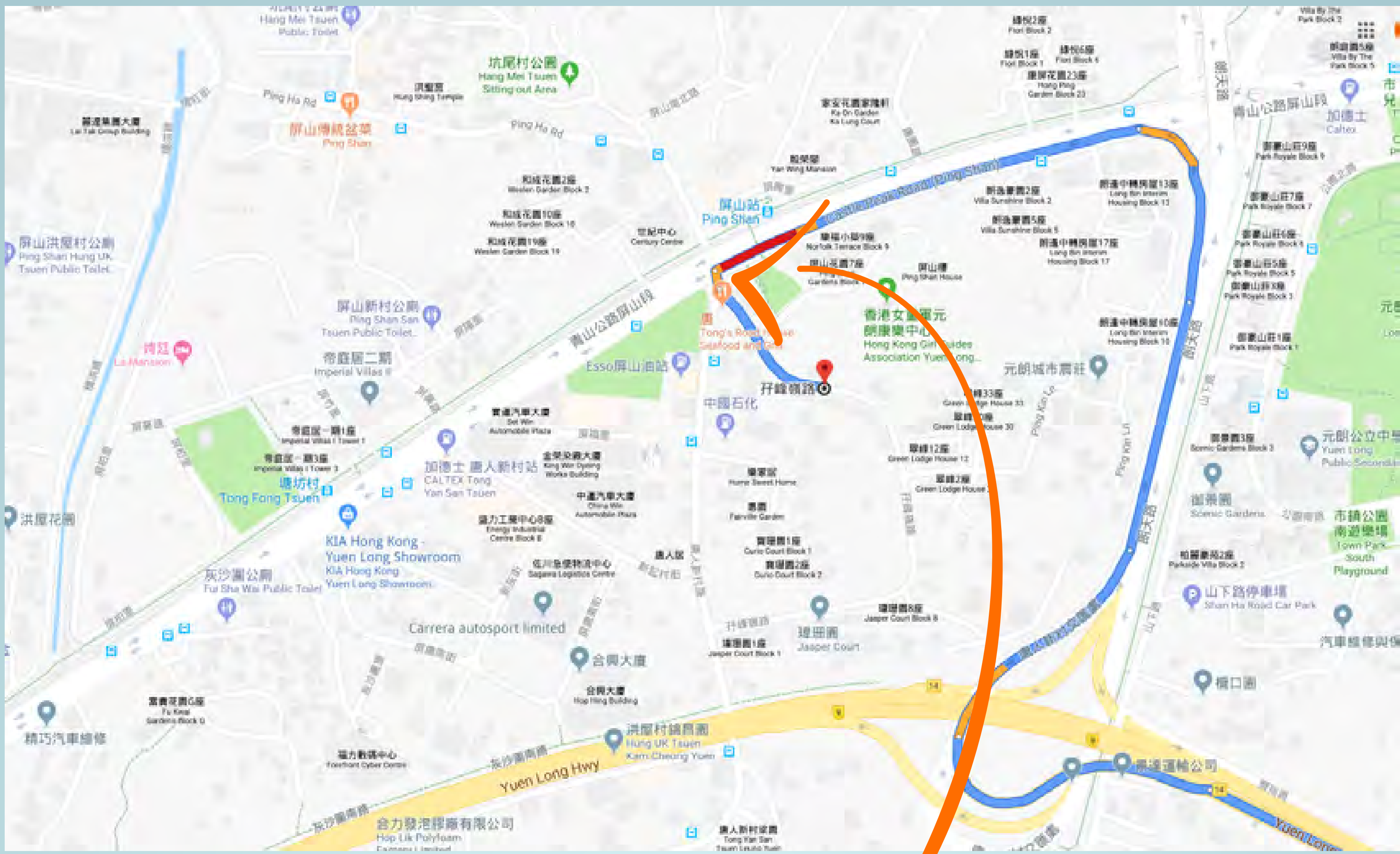
香港城市大學水產流動獸醫服務

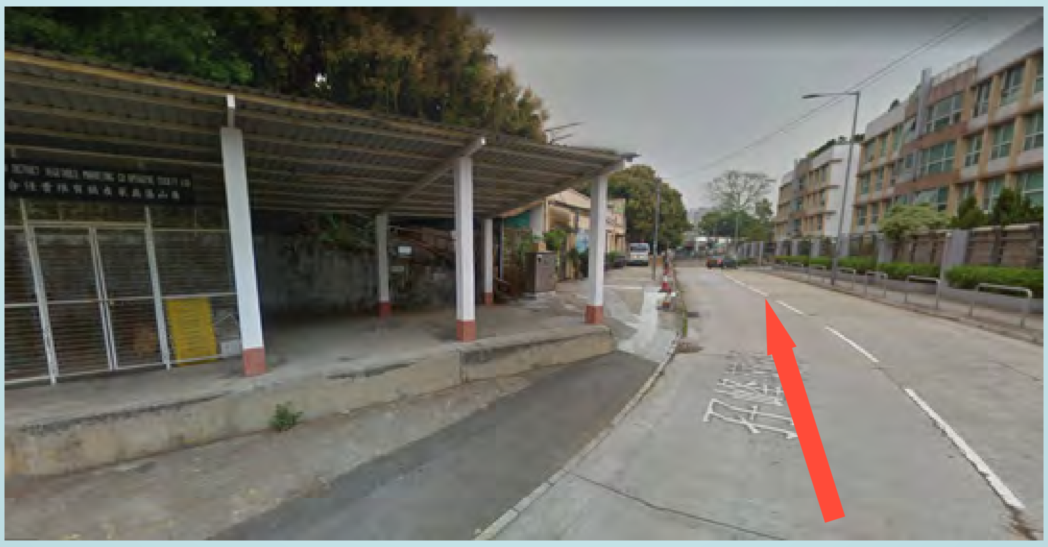
Prof. Sophie St-Hilaire 沈藹莉教授

[redacted]

水產流動獸醫服務聯絡電話: 5596-0777

元朗屏山孖峰嶺香港農業聯合會辦事處





Jockey Club College of Veterinary Medicine and Life Sciences
in collaboration with Cornell University

Appendix K list of farmers participating in AMU workshop

5/6/2019 水產養殖工作坊

貴賓名單 Guest List

姓名 Name	公司/機構 Company/Organisation	電話 phone number	簽名 Signature
[redacted]	香港創新環保漁業	[redacted]	
[redacted]		[redacted]	
[redacted]		[redacted]	
[redacted]		[redacted]	
[redacted]		[redacted]	
[redacted]	香港新界養魚協進會	[redacted]	
[redacted]	香港漁民團體協會	[redacted]	
[redacted]	香港漁民團體協會	[redacted]	
[redacted]	川上農莊	[redacted]	
[redacted]	香港錦鯉會	[redacted]	
[redacted]		[redacted]	
[redacted]		[redacted]	
[redacted]		[redacted]	
[redacted]	浸會大學	[redacted]	
[redacted]	浸會大學	[redacted]	
[redacted]		[redacted]	
[redacted]		[redacted]	

[redacted]	雲峰園	[redacted]	

香港城市大學 City University of Hong Kong Cornell University
Jockey Club College of Veterinary Medicine and Life Sciences
in collaboration with Cornell University

5/6/2019 水產養殖工作坊

貴賓名單 Guest List

姓名 Name	公司/機構 Company/Organisation	電話 phone number	簽名 Signature
[redacted]	AFCD		
	AFCD		
	AFCD		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CityU

Jockey Club College of Veterinary Medicine and Life Sciences

香港城市大學
City University of Hong Kong

in collaboration with Cornell University

BASIC FISH MEDICINE FOR YOUR PRACTICE

Dr Richmond Loh

DipProjMgt, BSc, BVMS, MPhil (Pathology), MANZCVS (Aquatics& Pathobiology), CertAqV, Fellow WAVMA

Dr Richmond Loh is based in Perth, is an aquatic veterinarian & fish pathologist, consulting as The Fish Vet, servicing all aspects of ornamental pet fish owners including hobbyists, public aquaria, retailers, wholesalers and fish farmers since 2002. His is famously known in veterinary circles for "Fish Vetting Essentials" book, and in fish hobbyists circles featuring in "The Fish Doctor" YouTube Channel. He served as the 2014 President of the World Aquatic Veterinary Medical Association (WAVMA), and Secretary of the Aquatic Animal Health Chapter of the ANZCVS. Dr Loh graduated from Murdoch University and is an Adjunct Senior Lecturer, has a Masters in veterinary pathology, Memberships in Aquatic Animal Health and Pathobiology, is a Certified Aquatic Veterinarian and a Distinguished Fellow of the WAVMA.

Topic covered

- common diagnostics and diseases of koi fish
- practical exercise on diagnostics used in fish medicine (i.e. gill biopsies, skin scrapes, &water testing)
- case studies including common treatment strategies for parasitic, bacterial, & water quality problems.

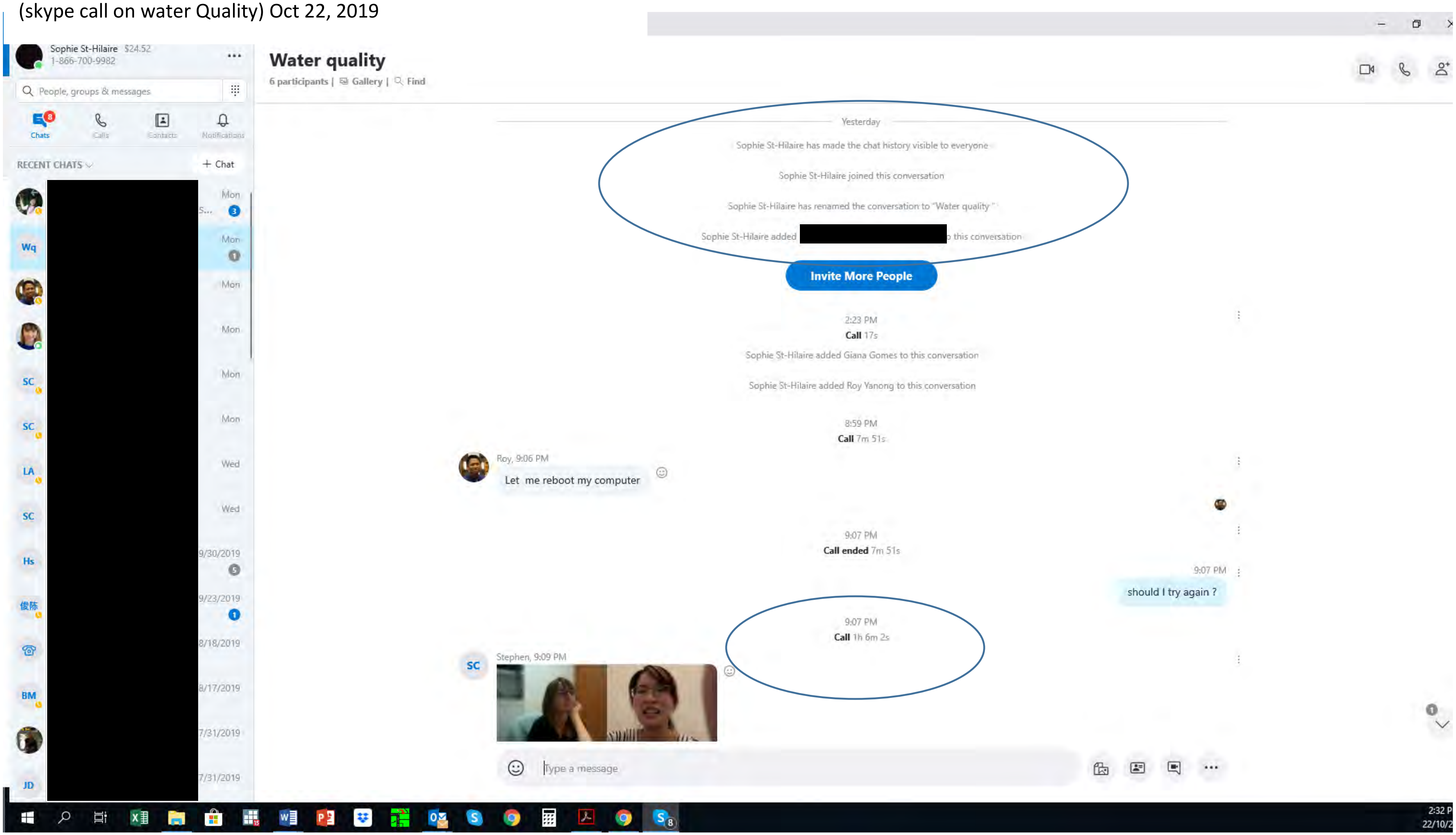
Date: 5 June 2019, Wednesday
Time: 7:00 pm to 10:00 pm (Light Dinner will be available at 6:30pm)
Venue: CP211, CityU School of Continuing and Professional Education
ChinaChem Golden Plaza, UG2 Floor
77 Mody Road, Tsim Sha Tsui East
Fee: HKD180

Registration:
http://www.cityu.edu.hk/jcc/links/20190605CPE.asp

Enquiries: Tel : (852) 3442 6138 Email: cvmls.cpe@cityu.edu.hk

Appendix I

(skype call on water Quality) Oct 22, 2019



CityU

Jockey Club College of Veterinary Medicine and Life Sciences
香港城市大學
City University of Hong Kong
in collaboration with Cornell University

Online Seminar
Water Quality Class for Vets

Speaker: Dr Richmond Loh
Date: 3 December 2020, Thursday
Time: 7:00 pm to 9:00 pm

scan here

Registration: https://www.cityu.edu.hk/jcc/20201203CPE

Good water quality is critical for healthy fish. Poor water quality can lead to primary pathology, as well as secondary disease issues in fish. Water quality can also influence your treatment choices. As part of an aquatic animal veterinary service it is essential that veterinarians and technicians know how to assess water quality, and that they are aware of the normal ranges for key water parameters important to sustain good fish health. This webinar will review the relevant water quality parameters to monitor as part of a fish veterinary practice, and the clinical signs you may see in fish associated with different common water quality issues. Dr. Loh will also discuss strategies used to mitigate water quality problems in veterinary practice.

Dr Richmond Loh

BSc, BVMS, MPhil (Pathology), MANZCVS (Aquatics& Pathobiology), CertAqV, Fellow WAVMA

Graduating from Murdoch University in 2001, Dr Loh followed his passion of fish to take his first post as a fish pathologist intern at DPIPWE in Tasmania. His aquatic work encompassed salmonids, oyster and abalone health monitoring and pathology. There, Dr Loh began consulting with pet fishes as "The Fish Vet". Now based in Perth (Western Australia), he is joined by a team spread across Australia to provide veterinary, and pathology services for a range of clients including pet fish, display aquaria, retailers and fish farmers. He has been admitted to the Australian and New Zealand College of Veterinary Scientists by examinations in both the subjects of Pathobiology, and in Medicine & Management of Aquaculture Species. He is a Certified Aquatic Veterinarian and has been awarded the George Alexander International Fellowship by the International Specialised Skills Institute. He has also been inducted as a Fellow of the World Aquatic Veterinary Medical Association. He promotes aquatic veterinary medicine by producing educational materials (http://tinyurl.com/thefishdoctor).

Enquiries: Tel : (852) 3442 6138 Email: cvmls.cpe@cityu.edu.hk

賽馬會動物醫學及生命科學院
香港城市大學
City University of Hong Kong
in collaboration with Cornell University

網上講座

香港魚排養殖魚病系列 -
海蝨！如何及早發現，診斷，治療及預防

海蝨是香港魚排養殖在冬季常見問題之一。這個講坐會包括以下話題:

- 如何知道魚類被海蝨感染及初步辨認海蝨
- 如何控制，及有效地治療海蝨感染
- 城市大學水產獸醫小組過往兩年醫療結果及心得

日期: 2020年12月17日(星期四)

時間: 上午11:00至下午12:00

講座連結: https://cityu.zoom.us/j/99165452987
登入密碼527375

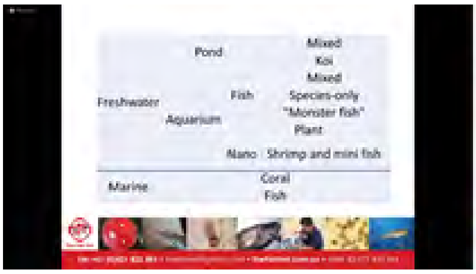
講座連結二維碼

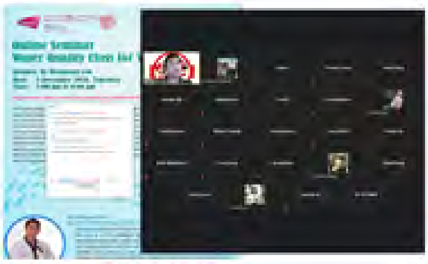
請先下載 Zoom 應用程式

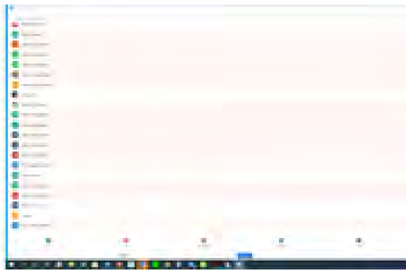
Download in App Store | Download in Google Play | Download for Window

香港城市大學水產流動獸醫服務
Prof. Sophie St-Hilaire 沈藹莉教授
[redacted]
水產流動獸醫服務聯絡電話: 5596-0777

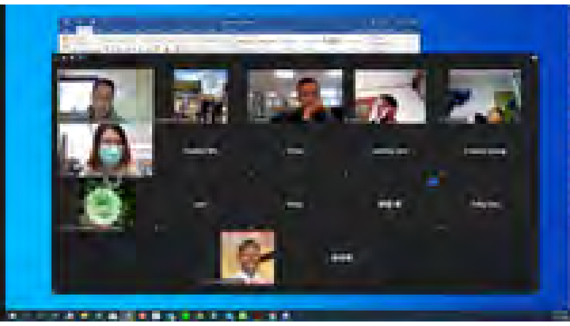
Screen captures of the participants for the veterinarian workshop n=31

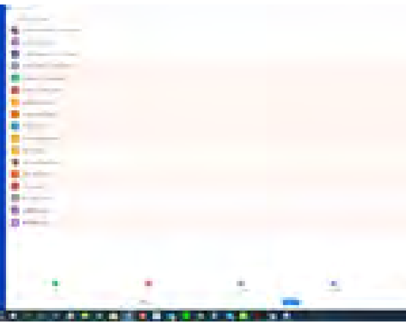






Screen captures for the farmer workshop n=34





Organic farmer meeting

Appendix J

Annual Fish Health internal summary up to April 2020

Appendix J

Outline of Fish health issues (internal report)

April 2020

The following are the common causes of disease that our team has observed over the last 12 months.

- Salt water mortality cases (50 cases)
    - Bacterial infections
        - *Streptococcus iniae*
        - *Vibrio* spp.
    - Parasite infections
        - *Cryptocaryon irritans*
        - *Tricodina spp.*
        - *Uronema spp.*
        - *Caligus* spp. (sea lice)
        - Monogenean parasites
    - Viral infections (irrido virus)
    - Water quality (salinity or nitrogenous waste issues in recirculation systems)
- Fresh water mortality cases (22 cases)
    - Water quality issues
        - Knowledge of water quality and mitigation strategies for different issues is low in the industry. Common issues facing farmers in Hong Kong include:
            - Fluctuation pH
                - Low alkalinity
            - Anoxic Turnover
            - High Total Ammonia
    - Bacterial diseases
        - *Aeromonas hydrophila*
        - *Edwardsiella Tarda*
        - others
    - Parasite diseases
        - I*chthyophonis multiphilis*
        - *Oodinium* spp.
        - *Tricodina*
        - Monogenean parasites

A common problem to both fresh and salt water farming in Hong Kong is issue around the removal of dead fish from the aquatic environment.   This is likely exacerbating infectious disease spread within and between farms.

附錄 K

預計成果及項目影響

項目預計會帶來的成果和影響，及有關評估

項目預計會帶來的成果和影響 （例如：項目及其成果／影響的持續性、項目成果的推廣價值及潛質、對本地漁業社羣及整個漁業的貢獻）
成果: • 按照對香港水產養殖業的影響程度，而排列的重點疾病之年度清單 • 透過城市大學設立獸醫服務,以配合漁護署的魚類健康檢查計劃. • 通過擬定計劃提供的年度獸醫服務摘要,包括經由城市大學設立的獸醫藥劑處銷售的水產動物用藥品. • 在香港使用 EMB 以對抗海水魚體外寄生蟲的手冊 • 關於 EMB 的研究科學文獻,概述了最低殘留標準的有效性和體葯期 • 有關於至少多一種影響本港水產養殖業的傳染病的干預策略的手冊和科學文獻 • 培訓兩名水生動物獸醫 • 城市大學獸醫學本科課程中, 2 個魚類健康課程 • 3 個持續專業發展課程(CPD),每個課程 20 人 • 兩個業界魚類健康工作坊,有 20-50 人參加 • 對項目進行最終評估,並就如何解決未來在香港的水產養殖業的獸醫需求提出建議 **影響:** • 提高水產動物獸醫服務和診斷能力和水準 • 通過早期發現和提高治療效果,減少由疾病爆發引致的總體死亡率. • 改善了本港水產養殖業在魚類健康、動物福利、生產力及環境方面的可持續性. • 以証據為基礎的疾病干預策略,以改善食品安全 • 提高消費者對香港魚類產品的信心.

活動概要*（請根據時序列出擬議項目的所有活動及工作時間表，並提供活動資料。）*

分享項目成果／經驗的方法
• 養殖場訪問期間可以加強獸醫與養殖戶之間的溝通。 • 獸醫透過實習培訓,可以提供臨床服務。 • 為獸醫開設持續專業進修(CPD) 課程.。 • 將魚類健康課程納為於獸醫學本課(BVM)課程內,令新的獸醫畢業生都有相關的知識。 • 漁民工作坊,可以促進業界提升處理魚類健康. • 為香港獸醫和水產養殖戶，提供幹幹預策略和水產動物健康手冊(即以 EMB 來處理體外寄生蟲)（在漁護處網站可查閱,並在工作坊派發，及由獸醫及飼料銷售者分發）。 • 在當地研討會上發表報告。 • 向本地媒體發布與項目有關的資訊 • 投稿到著名的科學期刊

成效指標（指標必須是具體、可量化及可實現的）（例如：參與主要活動的受惠者人數、對漁業的預期貢獻、產量／質素改變）		收集資料方法	成就
主要指標一：服務部份	至少有60的水產養殖戶， 可在這為期2年計劃內， 使用水產動物獸醫服務.	☐ 參與項目人士的登記資料 ☐ 評估問卷 ☑ 跟進調查 ☐ 其他方法，請註明：………………………………………	我們招募67位客戶使用我們的服務（附錄D）。 我們高估了使用我們服務的魚農人數。
主要指標二：研究部份	每12個月， 就確定,研究需求和重點，發表魚類健康報告	☐ 參與項目人士的登記資料 ☐ 評估問卷 ☐ 跟進調查 ☑其他方法: 漁護署魚類健康數據庫和獸醫服務數據庫分析 請註明： ………………………………………	• 我們每月向漁護署提供一個電子表格，其中包含所有個案及用藥指示。這些資料在附錄C中進行了總結。我們也有每月更新抗生素抗藥性測試資料（在附錄G中進行了總結）。 • 我們還回顧了香港發現的水生動物疾病的文獻（附錄L）。
主要指標三：研究部份	制定至少2個魚類健康問題的干預策略	☐ 參與項目人士的登記資料 ☐ 評估問卷 ☐ 跟進調查 ☑ 其他方法: 進行實驗和/或實地研究， 以評估干預策略. 請註明：………………………………………	• 我們成功治療了海蝨 (sea lice)，並製定了在石斑魚中使用甲氨基阿維菌素 (Emamectin benzoate) 的方案。 • 我們嘗試用甲苯咪唑 (Mebendazole) 治療纖毛原生動物 (ciliated protozoans)，但未成功。
主要指標四：	就每一個幹預策略評估，做一份由同儕審查的文稿和一份獸醫手冊。. 這些資料會透過漁護署的網站發佈，並為持續	☐ 參與項目人士的登記資料 ☐ 評估問卷 ☐ 跟進調查	我們發表了用甲氨基阿維菌素成功治療海蝨的報導（附錄F）。

研究部份	專業發展(CPD)課程和工作坊的一部份。	☑ 其他方法 請註明 ： 可量化的產品	
主要指標五：研究部份	利用通過本研究項目制定的新干預策略的70%的水產養殖者，將汇報其魚類健康狀況會有所改善(即死亡率減半)。我們將透過對漁場進行後續探訪，評估我們的治療成效。	☐ 參與項目人士的登記資料 ☐ 評估問卷 ☑ 跟進調查 ☐ 其他方法， 請註明：......................................	魚農對海蝨的新治療方法感到滿意，但產品成本稍高。我們在實地考察期間採訪了客戶。
主要指標六： 外展部份	兩名接受了水產動物醫學培訓的獸醫	☑ 參與項目人士的登記資料 ☐ 評估問卷 ☐ 跟進調查 ☐ 其他方法， 請註明：......................................	完成
主要指標七： 外展部份	三個CPD課程，每個課程有20名獸醫學員	☑ 參與項目人士的登記資料 ☐ 評估問卷 ☐ 跟進調查 ☐ 其他方法， 請註明：....................................	受到2019新型冠狀病毒的影響，我們只能提供兩門持續專業進修(CPD) 課程（附錄I）。
主要指標八：外展部份	兩場行業工作坊,每場活動有20-50名參加者	☑ 參與項目人士的登記資料 ☐ 評估問卷 ☐ 跟進調查 ☐ 其他方法， 請註明：................................	我們提供了四場行業工作坊（附錄I）。
主要指標九： 外展	在城市大學舉辦了兩個魚類健康課程。我們現有12名學生參加。預計明年有20名學生參加。	☑ 參與項目人士的登記資料 ☐ 評估問卷 ☐ 跟進調查 ☐ 其他方法， 請註明：................................	我們舉辦了三個魚類健康課程（約53名學生）。

部份			
主要指標十： 評估方案	項目評估報告,包括對項目未來的建議	☐ 參與項目人士的登記資料 ☐ 評估問卷 ☐ 跟進調查 ☑其他方法: 分析我們的成本和收益(即關鍵指標表現) 請註明：………………………………………	我們已提交了另一項提案SFDF_0042，並提出了對未來三年的建議。

Appendix L

Hong Kong Marine Fish disease survey (data summarized from AFCD)

Table 1. Pathogens/diseases reported from marine net-pen fish farms in Hong Kong. The data are from two different sources, the Agriculture, Fisheries, and Conservation Department of the Hong Kong Specieal Administrative Region, SAR (AFCD) and Fish Health Ambulatory Service of the City University of Hong Kong (FHAS).

Pathogen	Report date	Fish culture zone or general location [1]	Affected fish species	Source of data
Viruses				
Iridovirus	May 24, 2011	Yim Tin Tsai (East)	Green grouper	AFCD
Iridovirus	August 30, 2011	Yung Shue Au	Green grouper	AFCD
Iridovirus	June 28, 2012	Lo Tik Wan	Sweetlip	AFCD
Iridovirus	July 5, 2012	Yim Tin Tsai	Potato cod	AFCD
Iridovirus	August 16, 2013	Kau Sai	Hybrid grouper	AFCD
Iridovirus	December 8, 2014	Tai Tau Chau	Hybrid grouper	AFCD
Nervous necrosis virus (NNV)	November 26, 2013	Yung Shue Au	Hybrid grouper	AFCD
Nervous necrosis virus (NNV)	December 8, 2014	Tai Tau Chau	Hybrid grouper	AFCD
Nervous necrosis virus (NNV)	June 5, 2015	O Pui Tong	Giant grouper	AFCD
Nervous necrosis virus (NNV)	June 5, 2015	O Pui Tong	Green grouper	AFCD
Nervous necrosis virus (NNV)	June 8, 2015	Yung Shue Au	Hybrid grouper	AFCD
Nervous necrosis virus (NNV)	July 15, 2015	Yung Shue Au	Hybrid grouper	AFCD
Nervous necrosis virus (NNV)	May 27, 2016	Tai Tau Chau	Hybrid grouper	AFCD
Nervous necrosis virus (NNV)	November 29, 2017	Kau Sai	Hybrid grouper	AFCD
Read sea bream iridovirus (RSIV)	May 11, 2015	Tai Tau Chau	Hybrid grouper	AFCD
Read sea bream iridovirus (RSIV)	March 8, 2016	Kau Sai	Hybrid grouper	AFCD
Read sea bream iridovirus (RSIV)	March 30, 2016	O Pui Tong	Green grouper	AFCD
Read sea bream iridovirus (RSIV)	September 7, 2016	Yim Tin Tsai	Hybrid grouper	AFCD
Read sea bream iridovirus (RSIV)	September 18, 2017	Sok Kwu Wan	Pompano	AFCD
Read sea bream iridovirus (RSIV)	November 29, 2017	Kau Sai	Hybrid grouper	AFCD
Unknown (suspected viral infection)	September 3, 2019	Tai Po	Batfish	FHAS
Unknown (potential viral infection)	September 9, 2019	Sai Kung	Batfish	FHAS
Bacteria				
Aeromonas salmonicida	October 31, 2013	Sok Kwu Wan	Black croaker	AFCD
Aeromonas salmonicida	October 31, 2013	Sok Kwu Wan	Cobia	AFCD
Aeromonas salmonicida	October 31, 2013	Sok Kwu Wan	Red drum	AFCD
Photobacterium damselae	December 17, 2015	Yim Tin Tsai	Hybrid grouper	AFCD
Photobacterium damselae	January 13, 2016	Yung Shue Au	Hybrid grouper	AFCD
Photobacterium damselae	December 28, 2016	Yim Tin Tsai	Pompano	AFCD
Photobacterium damselae	January 5, 2017	Cheung Sha Wan	Pompano	AFCD
Photobacterium damselae	April 23, 2017	Tap Mun	Rabbit fish	AFCD
Photobacterium damselae	June 22, 2017	Cheung Sha Wan	Blackspotted croaker	AFCD
Photobacterium damselae	June 22, 2017	Cheung Sha Wan	Pompano	AFCD
Photobacterium damselae	June 29, 2017	Sok Kwu Wan	Pompano	AFCD

Photobacterium damselae	August 7, 2017	Sok Kwu Wan	Pompano	AFCD
Photobacterium damselae	September 18, 2017	Sok Kwu Wan	Pompano	AFCD
Photobacterium damselae	October 13, 2017	Sok Kwu Wan	Pompano	AFCD
Streptococcus iniae	April 23, 2017	Tap Mun	Rabbit fish	AFCD
Streptococcus iniae	June 29, 2017	Sok Kwu Wan	Pompano	AFCD
Streptococcus iniae	October 30, 2017	Sok Kwu Wan	Crescent sweetlips	AFCD
Streptococcus iniae	October 5, 2018	Sai Kung	Pompano	FHAS
Tenacibaculum maritimus	April 5, 2016	Cheung Sha Wan	Star snapper	AFCD
Vibrio alginolyticus	November 8, 2011	Leung Shuen Wan	Green grouper	AFCD
Vibrio alginolyticus	November 8, 2011	Leung Shuen Wan	Mangrove snapper	AFCD
Vibrio alginolyticus	May 22, 2012	Sok Kwu Wan	Sweetlip	AFCD
Vibrio alginolyticus	June 6, 2012	Lo Fu Wat	Giant grouper	AFCD
Vibrio alginolyticus	June 11, 2012	Sok Kwu Wan	Duskytail grouper	AFCD
Vibrio alginolyticus	June 28, 2012	Lo Tik Wan	Sweetlip	AFCD
Vibrio alginolyticus	August 8, 2012	Po Toi	Mangrove snapper	AFCD
Vibrio alginolyticus	August 8, 2012	Cheung Sha Wan	Cobia	AFCD
Vibrio alginolyticus	August 8, 2012	Cheung Sha Wan	Red drum	AFCD
Vibrio alginolyticus	August 8, 2012	Cheung Sha Wan	Greater amberjack	AFCD
Vibrio alginolyticus	August 27, 2012	Cheung Sha Wan	Red drum	AFCD
Vibrio alginolyticus	October 5, 2012	Sok Kwu Wan	Black croaker	AFCD
Vibrio alginolyticus	May 11, 2015	Tai Tau Chau	Hybrid grouper	AFCD
Vibrio alginolyticus	June 5, 2015	O Pui Tong	Green grouper	AFCD
Vibrio alginolyticus	September 14, 2015	Sok Kwu Wan	Crescent sweetlips	AFCD
Vibrio alginolyticus	September 30, 2015	Sok Kwu Wan	Pompano	AFCD
Vibrio alginolyticus	September 30, 2015	Sok Kwu Wan	Red pargo	AFCD
Vibrio alginolyticus	September 30, 2015	Sok Kwu Wan	Red snapper	AFCD
Vibrio alginolyticus	November 20, 2015	Cheung Sha Wan	Cobia	AFCD
Vibrio alginolyticus	January 15, 2016	Lo Tik Wan	Pompano	AFCD
Vibrio alginolyticus	February 18, 2016	Tai Tau Chau	Hybrid grouper	AFCD
Vibrio alginolyticus	March 8, 2016	Kau Sai	Hybrid grouper	AFCD
Vibrio alginolyticus	January 17, 2017	Sha Tau Kok	Hybrid grouper	AFCD
Vibrio alginolyticus	June 29, 2017	Sok Kwu Wan	Pompano	AFCD
Vibrio alginolyticus	October 13, 2017	Sok Kwu Wan	Pompano	AFCD
Vibrio alginolyticus	November 29, 2017	Kau Sai	Hybrid grouper	AFCD
Vibrio harveyi	March 15, 2015	Yim Tin Tsai (East)	Hybrid grouper	AFCD
Vibrio parahaemolyticus	April 5, 2016	Cheung Sha Wan	Star snapper	AFCD
Vibrio parahaemolyticus	June 29, 2017	Sok Kwu Wan	Pompano	AFCD
Vibrio parahaemolyticus	August 7, 2017	Sok Kwu Wan	Pompano	AFCD
Vibrio parahaemolyticus	October 30, 2017	Sok Kwu Wan	Emperor snapper	AFCD
Vibrio vulnificus	October 31, 2013	Sok Kwu Wan	Black croaker	AFCD
Vibrio vulnificus	October 31, 2013	Sok Kwu Wan	Cobia	AFCD

Vibrio vulnificus	October 31, 2013	Sok Kwu Wan	Red drum	AFCD
Vibrio vulnificus	November 18, 2015	Lo Tik Wan	Hybrid grouper	AFCD
Vibrio vulnificus	September 7, 2016	Yim Tin Tsai	Hybrid grouper	AFCD
Vibrio vulnificus	November 15, 2016	Kau Sai	Pompano	AFCD
Vibrio vulnificus	January 5, 2017	Cheung Sha Wan	Pompano	AFCD
Vibrio sp.	October 10, 2017	Sok Kwu Wan	Yellow croaker	AFCD
Vibrio sp.	October 5, 2018	Tai Po	Pompano	FHAS
Unknown bacteria (suspected)	October 15, 2018	Sai Kung	Rabbit fish	FHAS
Unknown bacteria (suspected secondary infection)	October 30, 2018	Sai Kung	Pompano	FHAS
Unknown bacteria (suspected secondary infection)	October 31, 2018	Sai Kung	Pompano	FHAS
Unknown bacteria (suspected secondary infection)	November 12, 2018	Sai Kung	Pompano	FHAS
Unknown bacteria	December 17, 2018	Sai Kung	Pompano	FHAS
Unknown bacteria	April 12, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Unknown bacteria	April 17, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Unknown bacteria	April 24, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Unknown bacteria	April 26, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Unknown bacteria	April 30, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Unknown bacteria	May 2, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Unknown bacteria	May 6, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Unknown bacteria	May 7, 2019	Sai Kung	Pompano	FHAS
Unknown bacteria	May 17, 2019	Sai Kung	Pompano	FHAS
Unknown bacteria	May 22, 2019	Cheung Sha Wan	Croaker	FHAS
Unknown bacteria	June 21, 2019	Tai Tau Chau	Grouper	FHAS
Unknown bacteria	July 2, 2019	Tai Tau Chau	Grouper	FHAS
Unknown bacteria (secondary bacterial infection)	August 27, 2019	Tai Po	Batfish	FHAS
Unknown bacteria	September 3, 2019	Tai Po	Batfish	FHAS
Suspected bacterial outbreak	November 20, 2018	Lamma Island	Hybrid grouper	FHAS
Suspected bacterial outbreak	November 30, 2018	Lamma Island	Hybrid grouper	FHAS
Parasites				
Copepoda				
Sea lice (*Caligus*)	November 9, 2012	Yim Tin Tsai (East)	Green grouper	AFCD
Sea lice (*Caligus*)	March 15, 2015	Yim Tin Tsai (East)	Hybrid grouper	AFCD
Sea lice (*Caligus*)	June 8, 2015	Yung Shue Au	Hybrid grouper	AFCD
Sea lice (*Caligus*)	July 15, 2015	Yung Shue Au	Hybrid grouper	AFCD
Sea lice (*Caligus*)	December 14, 2015	Yung Shue Au	Hybrid grouper	AFCD
Sea lice	January 17, 2017	Sha Tau Kok	Hybrid grouper	AFCD
Sea lice	November 29, 2018	Yim Tin Tsai	Hybrid grouper	FHAS
Sea lice	February 28, 2019	Sam Mun Tsai	Grouper	FHAS
Sea lice	April 12, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Sea lice	April 17, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Sea lice	April 24, 2019	Yim Tin Tsai	Hybrid grouper	FHAS

Sea lice	April 26, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Sea lice	April 30, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Sea lice	May 2, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Sea lice	May 6, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Sea lice	March 17, 2020	Cheung Sha Wan	Hybrid grouper	FHAS
Sea lice	April 1, 2020	Cheung Sha Wan	Hybrid grouper	FHAS
Sea lice	April 2, 2020	Tai Tau Chau	Hybrid grouper	FHAS
Sea lice	April 8, 2020	Cheung Sha Wan	Hybrid grouper	FHAS
Sea lice	April 14, 2020	Tai Tau Chau	Hybrid grouper	FHAS
Sea lice	April 15, 2020	Cheung Sha Wan	Hybrid grouper	FHAS
Sea lice	April 21, 2020	Tai Tau Chau	Hybrid grouper	FHAS
Isopoda				
Unknown	February 8, 2011	Yim Tin Tsai	Giant grouper	AFCD
Unknown	November 6, 2012	Yim Tin Tsai	Green grouper	AFCD
Microsporea				
Glugea	February 18, 2016	Tai Tau Chau	Hybrid grouper	AFCD
Glugea	March 8, 2016	Kau Sai	Hybrid grouper	AFCD
Glugea	March 30, 2016	O Pui Tong	Green grouper	AFCD
Glugea	May 27, 2016	Tai Tau Chau	Hybrid grouper	AFCD
Glugea	January 17, 2017	Sha Tau Kok	Hybrid grouper	AFCD
Unknown	February 8, 2011	Yim Tin Tsai	Giant grouper	AFCD
Monogenea				
Benedenia sp.	February 18, 2016	Tai Tau Chau	Hybrid grouper	AFCD
Benedenia sp.	March 8, 2016	Kau Sai	Hybrid grouper	AFCD
Benedenia sp.	January 5, 2017	Cheung Sha Wan	Pompano	AFCD
Benedenia sp.	January 17, 2017	Sha Tau Kok	Hybrid grouper	AFCD
Dactylogyrus sp.	June 26, 2012	Yung Shue Au	Green grouper	AFCD
Dactylogyrus sp.	November 6, 2012	Yim Tin Tsai	Green grouper	AFCD
Dactylogyrus sp.	November 9, 2012	Yim Tin Tsai (East)	Green grouper	AFCD
Dactylogyrus sp.	August 16, 2013	Kau Sai	Hybrid grouper	AFCD
Dactylogyrus sp.	October 31, 2013	Sok Kwu Wan	Black croaker	AFCD
Dactylogyrus sp.	October 31, 2013	Sok Kwu Wan	Cobia	AFCD
Dactylogyrus sp.	October 31, 2013	Sok Kwu Wan	Red drum	AFCD
Dactylogyrus sp.	June 5, 2015	O Pui Tong	Green grouper	AFCD
Dactylogyrus sp.	September 14, 2015	Sok Kwu Wan	Crescent sweetlips	AFCD
Dactylogyrus sp.	July 31, 2020	Lamma Island	Hybrid grouper	FHAS
Unknown	December 17, 2018	Sai Kung	Pompano	FHAS
Unknown	April 12, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Unknown	April 17, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Unknown	April 24, 2019	Yim Tin Tsai	Hybrid grouper	FHAS

Unknown	April 26, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Unknown	April 30, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Unknown	May 2, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Unknown	May 6, 2019	Yim Tin Tsai	Hybrid grouper	FHAS
Protozoa				
Amyloodinium	December 17, 2018	Sai Kung	Pompano	FHAS
Brooklynella hostilis	May 22, 2012	Sok Kwu Wan	Sweetlip	AFCD
Brooklynella	July 12, 2011	Sok Kwu Wan	Duskytail grouper	AFCD
Brooklynella	June 11, 2012	Sok Kwu Wan	Duskytail grouper	AFCD
Brooklynella	November 22, 2012	Sok Kwu Wan	Pompano	AFCD
Brooklynella	October 30, 2017	Sok Kwu Wan	Crescent sweetlips	AFCD
Cryptocaryon irritans	November 8, 2011	Leung Shuen Wan	Green grouper	AFCD
Cryptocaryon irritans	November 8, 2011	Leung Shuen Wan	Mangrove snapper	AFCD
Cryptocaryon irritans	November 8, 2011	Leung Shuen Wan	Pompano	AFCD
Cryptocaryon irritans	October 5, 2012	Sok Kwu Wan	Black croaker	AFCD
Cryptocaryon irritans	November 6, 2012	Yim Tin Tsai	Green grouper	AFCD
Cryptocaryon irritans	November 9, 2012	Yim Tin Tsai (East)	Green grouper	AFCD
Cryptocaryon irritans	June 6, 2013	Tiu Cham Wan	Pompano	AFCD
Cryptocaryon irritans	October 31, 2013	Sok Kwu Wan	Black croaker	AFCD
Cryptocaryon irritans	October 31, 2013	Sok Kwu Wan	Cobia	AFCD
Cryptocaryon irritans	October 31, 2013	Sok Kwu Wan	Red drum	AFCD
Cryptocaryon irritans	September 14, 2015	Sok Kwu Wan	Crescent sweetlips	AFCD
Cryptocaryon irritans	September 14, 2015	Sok Kwu Wan	Greater amberjack	AFCD
Cryptocaryon irritans	September 30, 2015	Sok Kwu Wan	Pompano	AFCD
Cryptocaryon irritans	November 20, 2015	Cheung Sha Wan	Cobia	AFCD
Cryptocaryon irritans	December 14, 2015	Yung Shue Au	Hybrid grouper	AFCD
Cryptocaryon irritans	November 15, 2016	Kau Sai	Pompano	AFCD
Cryptocaryon irritans	June 22, 2017	Cheung Sha Wan	Blackspotted croaker	AFCD
Cryptocaryon irritans	June 22, 2017	Cheung Sha Wan	Pompano	AFCD
Cryptocaryon irritans	August 7, 2017	Sok Kwu Wan	Pompano	AFCD
Cryptocaryon irritans	September 18, 2017	Sok Kwu Wan	Pompano	AFCD
Cryptocaryon irritans	October 2, 2018	Sai Kung	Pompano	FHAS
Cryptocaryon irritans	October 22, 2018	Sai Kung	Whitemouth croaker	FHAS
Cryptocaryon irritans	October 22, 2018	Sai Kung	Pompano	FHAS
Cryptocaryon irritans	October 30, 2018	Sai Kung	Pompano	FHAS
Cryptocaryon irritans	October 31, 2018	Sai Kung	Pompano	FHAS
Cryptocaryon irritans	November 12, 2018	Sai Kung	Pompano	FHAS
Cryptocaryon irritans	April 13, 2019	Sai Kung	Pompano	FHAS
Cryptocaryon irritans	April 29, 2019	Sai Kung	Pompano	FHAS
Cryptocaryon irritans	May 7, 2019	Sai Kung	Pompano	FHAS
Cryptocaryon irritans	May 17, 2019	Sai Kung	Pompano	FHAS

Cryptocaryon irritans	May 20, 2019	Sai Kung	Pompano	FHAS
Cryptocaryon irritans	July 30, 2020	Tai Po	Batfish	FHAS
Scuticocilia	October 30, 2018	Sai Kung	Pompano	FHAS
Scuticocilia	October 31, 2018	Sai Kung	Pompano	FHAS
Scuticocilia	November 12, 2018	Sai Kung	Pompano	FHAS
Trichodina	February 8, 2011	Yim Tin Tsai	Giant grouper	AFCD
Trichodina	July 12, 2011	Sok Kwu Wan	Duskytail grouper	AFCD
Trichodina	November 8, 2011	Leung Shuen Wan	Green grouper	AFCD
Trichodina	July 5, 2012	Yim Tin Tsai	Potato cod	AFCD
Trichodina	August 16, 2013	Kau Sai	Hybrid grouper	AFCD
Trichodina	September 14, 2015	Sok Kwu Wan	Crescent sweetlips	AFCD
Trichodina	January 13, 2016	Yim Tin Tsai (East)	Hybrid grouper	AFCD
Trichodina	January 15, 2016	Lo Tik Wan	Pompano	AFCD
Trichodina	February 18, 2016	Tai Tau Chau	Hybrid grouper	AFCD
Trichodina	September 7, 2016	Yim Tin Tsai	Hybrid grouper	AFCD
Trichodina	December 28, 2016	Yim Tin Tsai	Pompano	AFCD
Trichodina	January 5, 2017	Cheung Sha Wan	Pompano	AFCD
Trichodina	June 29, 2017	Sok Kwu Wan	Pompano	AFCD
Trichodina	September 18, 2017	Sok Kwu Wan	Pompano	AFCD
Trichodina	October 13, 2017	Sok Kwu Wan	Pompano	AFCD
Trichodina	October 16, 2018	Sai Kung	Japanese eel	FHAS
Trichodina	December 17, 2018	Sai Kung	Pompano	FHAS
Uronema	March 8, 2016	Kau Sai	Hybrid grouper	AFCD
Uronema	March 30, 2016	O Pui Tong	Green grouper	AFCD
Uronema	April 5, 2016	Cheung Sha Wan	Star snapper	AFCD
Uronema	August 7, 2017	Sok Kwu Wan	Pompano	AFCD
Uronema	October 13, 2017	Sok Kwu Wan	Pompano	AFCD
Suspected scuticocilia	October 22, 2018	Sai Kung	Pompano	FHAS
Trematoda				
Sanguinicola	September 18, 2017	Sok Kwu Wan	Pompano	AFCD
Sanguinicolids	January 15, 2016	Lo Tik Wan	Pompano	AFCD
Unclassified				
Turbellarians	November 15, 2016	Kau Sai	Pompano	AFCD
Unknown	June 24, 2019	Sai Kung	Pompano	FHAS
Unknown (suspected parasitic problem)	September 5, 2019	Lamma Island	Cobia	FHAS
Gill parasite	March 17, 2020	Cheung Sha Wan	Star snapper	FHAS
Unknown issues				
Unknown	October 9, 2018	Sai Kung	Grouper	FHAS

[1] Some zones in this table are not found in the map of fish culture zones in Hong Kong (Figure x) (i.e. Tai Po, Sai Kung, Sam Mun Tsai, Lamma Island) and are the general location of the farm from which the pathogen/disease was reported (this is how the location was recorded in the original database). However, to be able to compare the zones, according to their locations, farmed species, disease issues, etc., and for clarification, the information below is provided:

- Tai Po includes two fish culture zones, Lo Fu Wat and Yung Shue Au
- Sai Kung includes following fish culture zones: Tap Mun, Kau Lau Wan, Sham Wan, Leung Shuen Wan, Tiu Cham Wan, Kai Lung Wan, Kau Sai, Ma Nam Wat, and Po Toi O
- Sam Mun Tsai includes two fish culture zones, Yim Tin Tsai and Yim Tin Tsai (East)
- Lamma Island includes two fish culture zones, Sok Kwu Wan and Lo Tik Wan

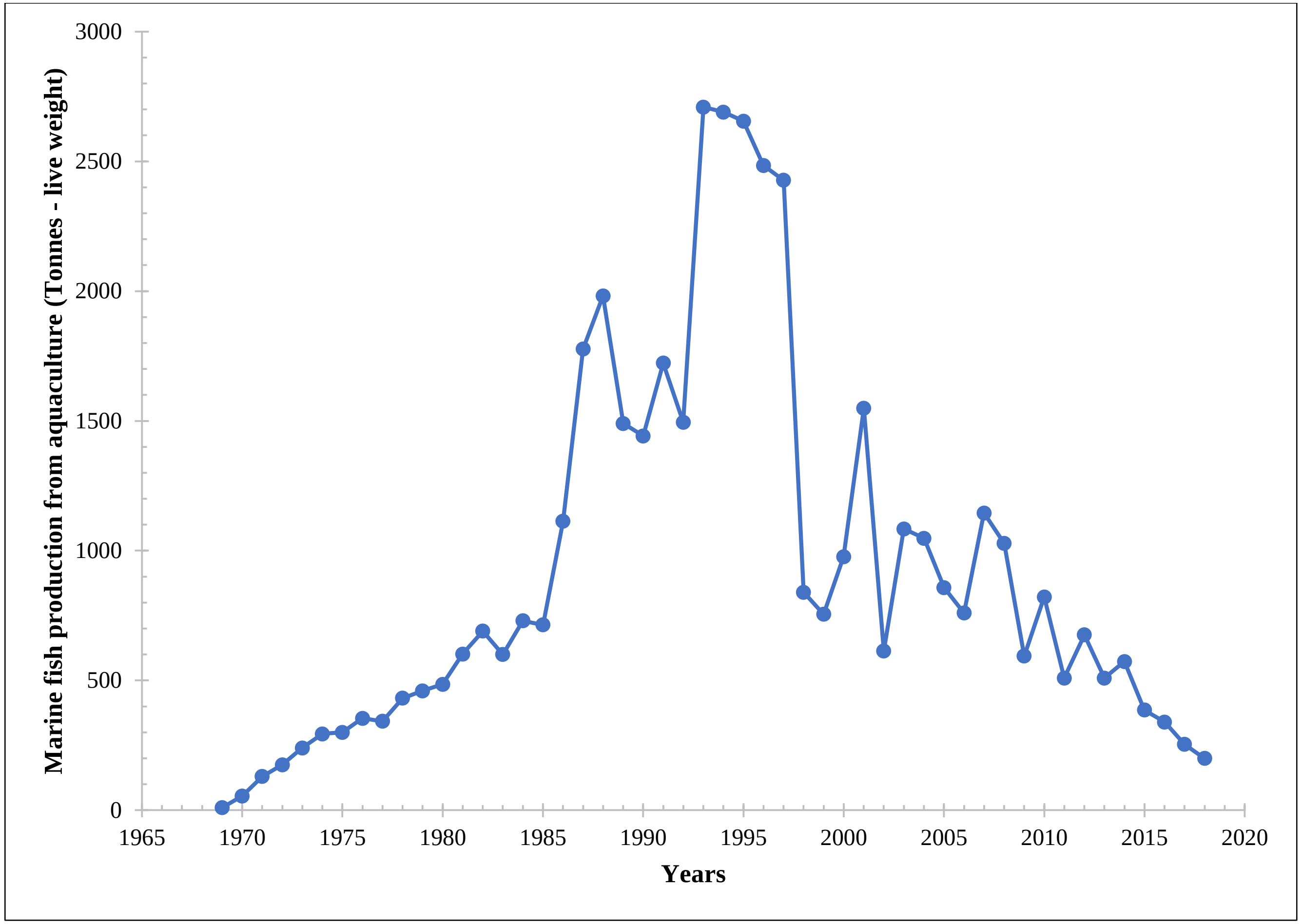


Figure 1. Marine fish production in Hong Kong during the years 1969-2018. The figure has been produced for this study using the data related to the production of major marine fish species farmed in Hong Kong (groups under the following names: areolate grouper, barramundi, goldlined seabream, greasy grouper, Hong Kong grouper, mangrove red snapper, orange-spotted grouper, Russell's snapper, silver seabream, snappers nei, snubnose pompano) from FishstatJ (FAO 2020).

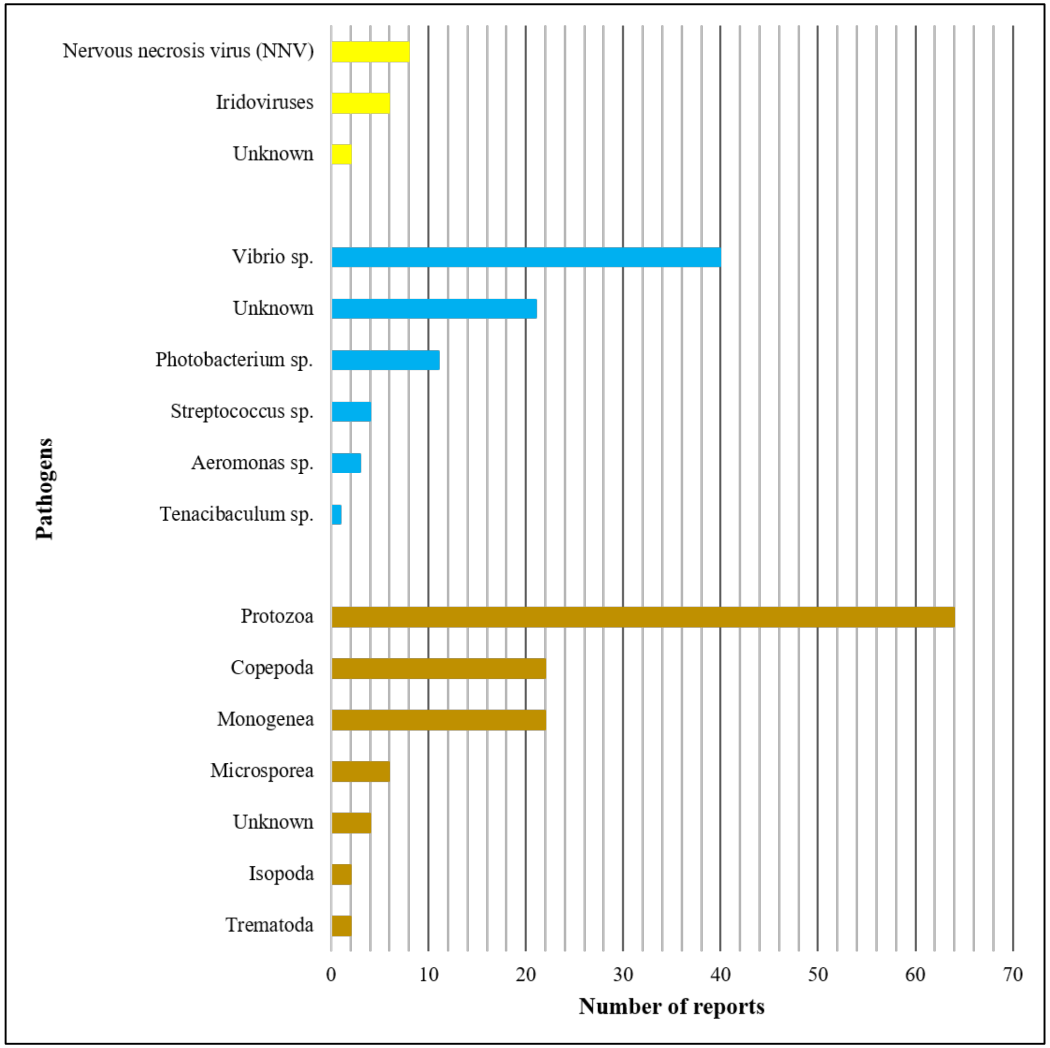


Figure 2. A summary of pathogens commonly reported from marine fish net-pen farms in Hong Kong according to the Hong Kong disease databases used in this study (AFCD and City University of Hong Kong). Yellow, blue, and brown colours represent viral, bacterial, and parasitic species, respectively.