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Review: A bibliometric survey of live feed for marine finfish and shrimp larval production

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Conflict of interest disclosure: All INVE researchers and individuals affiliated to University of Ghent, Belgium. Over the years, we have noticed a certain reluctance among these scholars towards accepting the relevance of copepods as live feed organisms.

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Permission to reproduce material from other sources: all sources are freely accessible for members of aquaculture societies and/or attendees of conferences (EAS, WAS and LARVI) and/or for the general public.

Clinical trial registration: not relevant.

Abstract

Aquaculture research contributes to development of the industry and practitioners depend on effective and understandable information about research findings. A bottleneck for increased diversification and efficient farming of larvae of marine finfish is lack of sufficient quantities of high quality live feed i.e. copepods. Number of scientific articles and conference contributions' mentioning live feed organisms is considered reflecting research activity and is used here as a proxy indicating awareness of importance amongst aquaculture researchers and producers. The percentage of live feed- of total aquaculture articles has steadily declined over the past decades, reaching ≤5%, ranking *Artemia* first followed by rotifers and then copepods in total frequency in WoS and in conference abstracts except for LARVI. Exponential increase of number of live feed WoS articles is in contrast to a stagnant numerical frequency of WAS and EAS conference abstracts mentioning live feed over time. Since aquaculture practitioners likely not get similar information as researchers there is a risk that exposure to new research will face a time-lag or even not reach these stakeholders and implementation of new discoveries will not happen properly. We imagine it lead to less innovation and diversification in marine finfish and shrimp production and propose a dissemination mitigation strategy.

KEYWORDS

conference abstracts, dissemination bias, peer reviewed articles, practitioners, text mining

1. INTRODUCTION

Aquaculture is one of the fastest developing food production sectors worldwide with an overall 5.8% annual increase during the period 2000 to 2016 (FAO, 2018). However, increasing the output of marine fish has proven difficult over the years as appropriate access to high quality live feed e.g. copepods is one of the primary bottlenecks in developing marine finfish production (e.g. Dhont et al., 2013; Rasdi and Qin, 2014; Nielsen et al., 2017).

A traditional feeding protocol for marine fish larvae starts with rotifers (wheel animals usually *Brachionus* spp.) as feed for a few days followed by feeding with various life stages of brine shrimp (*Artemia* spp.) until weaning on to formulated feed one or two weeks post-hatch (Øie et al., 2011). Rotifers occur naturally in fresh water and brackish water and *Artemia* in hypersaline environments. One disadvantage with their use as live feed for both marine fish and shrimp larvae is that they have inadequate amounts of highly unsaturated fatty acids (HUFA) (Støttrup and McEvoy, 2003; Øie et al., 2011; Nielsen et al., 2017), that are required for the development of the nervous system, eyes, pigmentation and general growth of marine larvae (Izquierdo and Koven, 2011). A major research effort has focused on enrichment of rotifers and *Artemia* with high-HUFA oil emulsions, so that when fed to marine fish and shrimp larvae the live prey will contain sufficient HUFA to cover their nutritional needs (Lubzens et al., 1989; Dhert et al., 2001; Øie et al., 2011; Das et al., 2012; Mahjoub et al., 2013). In contrast, the natural HUFA content and composition in marine free living copepods are considered nutritionally adequate (Rayner et al., 2017), which translate into better survival, development, growth and overall quality of fish larvae when fed copepods (Shields et al., 1999; Wilcox et al., 2006; Randazzo et al., 2018). Copepods, being 'natures choice', are the primary diet for most marine fish larval species in nature (e.g. Conceição et al., 2010), which is why supplementing or even substituting the above mentioned traditional live feed organisms with copepods is argued to enable a broader fish species production while improving the ones already being cultured (see Drillet et al., 2011). Despite these nutritious qualities, being backed up by numerous feeding trials reported in scientific contributions; copepods are still not widely implemented in the fish and shrimp larval rearing industry due to their production being more demanding (see Abate et al., 2015). Nevertheless, if the aim is to diversify marine fish production, then strong considerations on diversification of live feed products should be made (Drillet et al., 2011). Hence, an increased emphasis on live feed research is crucial for the future development of in particular the marine fish production industry.

It is our overall impression that the current fish and shrimp larval rearing strategy at the hatcheries is mainly to tailor the target species to the already established live feed organisms rather than to provide a specific and relevant live feed protocol eventually including alternative zooplankton species to each situation i.e. the difficult species to rear. This is why we hypothesize that the slow development of diversification in marine fish production is due, in part; to the limited exposure of new advances made within live feed research. Several live feed items besides the traditional *Artemia* and rotifers are used with various intensities e.g. polychaete larvae and molluscan veligers (see Howell, 1971 and Basford et al., 2019). However, these are far from well-studied and their present volume rather limited relative to the also quite underused copepods. Here we have decided to focus upon copepods as a novel feed organism besides the traditional high volume live feeds in our analysis. Hence, we aim at analyzing scientific awareness of the three live feed organisms *Artemia*, rotifer and copepod by quantifying the cumulative and temporal development of scientific live feed discussions. This will be done by analyzing when and how often these live feed items have been reported in articles over the past >4 decades in the peer reviewed scientific literature recorded in Web of Science WoS, and by consulting other available databases (Google Scholar GoS and Aquatic Sciences and Fisheries Abstracts ASFA). Additionally, since practitioners presumably seldom have daily access to the peer reviewed scientific articles unless they are open access and they most likely merely participate in conferences and fairs for in-service training, we consulted the proceedings from the largest worldwide covering comprehensive conferences within the framework of World of Aquaculture (WAS) from several of the society's chapters and European Aquaculture Society (EAS). We extracted information from the past approximately two decades concerning when and at what frequency the live feed organisms have been mentioned in oral and poster contributions at these multidisciplinary international aquaculture conferences. Additionally, we have done the same for LARVI - International fish & shellfish larviculture symposia organized by Gent University, Belgium from 1991 to 2017. This forum focuses more on targeted fish larval production and was hereby expected to discuss live feed aspects at a higher intensity than the broader WAS and EAS conferences encompassing all aspects of aquaculture. This is, to some extent, inspired by an article by Do and Skłodowski (2014) who used the same approach for extracting knowledge from a vast number of coleopteran studies by generating a word-cloud and further used statistical analysis, including regression analyses, as in the present study. Moreover, Do et al. (2015) also extracted knowledge by bibliometric and text mining tools concerning several animal species and identified species linked to various research categories from journal articles and conference contributions. Recently, a systematic review article was published where WoS data from more than 1700 articles was used to define small-scale fisheries and examined the role of science in shaping perceptions of who and what counts in small-scale fishery (Smith and Basurtu, 2019) and Borja et al. (2020) analyzed the most important grand challenges in marine ecology by analyzing reported international peer reviewed articles total number of citations and their annual citation rate during a 6-year period. Hence, by using bibliometric and text mining as a recognized approach for e.g. analyzing database tomography, a system, which includes algorithms for extracting multi-word phrase frequencies (reviewed in Kostoff et al., 2001), we have here discovered some interesting temporal trends among the awareness i.e. frequencies of using our selected live feed key words. Lastly, we suggest a future knowledge transfer and collaboration strategy to improve the current state.

2. MATERIALS AND METHODS

We have structured the analysis among the three most volumetric relevant live feed items fed to marine larval fish and shrimps. The temporal development of published literature on live feed organisms firstly presented *Artemia* followed by rotifer and lastly copepod in our WoS literature search. Therefore the chronology presented there follows all through our contribution. Numerous scientific topics are reported with a certain exponential growth in number of articles with time. In order to make a relevant anchor point i.e. qualifier to which our specialized live feed key words can be compared, we decided to use the term 'aquaculture' as a qualifier and compare the temporal development of live feed items with this broader term representing the entire aquaculture discipline.

2.1 Google Scholar

We searched Google Scholar (https://scholar.google.com) on October 30th 2020 using the search terms *aquaculture artemia*, *aquaculture rotifer*, and *aquaculture copepod* and noted the number of results from all available references which are shown as approximations (Google use the term “About”). Google Scholar did not present facilities for further analysis.

2.2 Web of Science (WoS) and Aquatic Sciences and Fisheries Abstracts (ASFA)

WoS is available at https://webofknowledge.com. WoS is a bibliographic database indexing content in highly cited peer-reviewed scholarly journals. The searches were limited to “Science Citation Index Expanded (SCI-EXPANDED) --1900-present” (excluding Social Sciences and Arts and Humanities indexes). Three searches were carried out on October 30th 2020 using search strings shown in Table 1. To exclude articles dealing with the non-feed ectoparasitic copepod ‘sea lice’ in aquaculture, it was necessary to add *NOT ("sea lice" OR "salmon louse" OR parasit*)* to the copepod search string. The searches were carried out as standard “Topic” searches. The results were then counted by publication year using the “Analyze Results” function in WoS.

ASFA is a bibliographic database specialized on “science, technology, management, and conservation of marine, brackish water, and freshwater resources and environments” (https://search.proquest.com /asfa/productfulldescdetail) and is available at proquest.com. Searches in ASFA October 30th 2020 used the same search strings as used in WoS and most likely there is a large fraction of hits in WoS there is included in ASFA. ASFA did not present facilities for further analysis.

2.3 World Aquaculture Society (WAS), European Aquaculture Society (EAS) and International fish & shellfish larviculture symposia (LARVI)

Meeting abstracts from several of the world’s leading aquaculture conference series organized by WAS (including World Aquaculture, AQUA, Aquaculture America and Asia-Pacific Aquaculture chapters) and EAS are freely available on the society’s homepages (https://www.was.org and https://www.aquaeas.eu). Meeting name, year, abstract titles, and abstract texts from these conferences were gathered from the periods WAS 1996-2016 and EAS 2007-2017, respectively, using a PHP-script and stored in a MySQL database table (script and database can be available from the data repository Zenodo). By querying the MySQL database using keywords describing each feed type (*Artemia*, rotifer, copepod), we could identify and count all abstracts containing at least one of these keywords along with number of occurrence of each keyword in each abstract. The query output was then transferred to a MS Excel spreadsheet for further analysis. For EAS abstracts, text mining was conducted as described above, but due to lack of discriminators between each abstract, a regular expression to recognize titles given in capital letters was added to the script to separate the contributions.

Book of Abstracts from LARVI (1991-2017) became available either in hard copy (1991 and 1995) or as pdf-files. The hard copy abstract books were scanned and the texts were extracted using Adobe Acrobat OCR software. The abstracts were then processed in electronic form as described above.

2.4 Statistical analysis

Statistical analysis and graphics were carried out using "R" (version 3.5.3, https://www.r-project.org/). Relevant WoS articles published over time were described by exponential functions whereas conference hits vs. time with simple linear regressions (see Table 2 for regression statistics). We tested if slopes of regression lines are different from zero. Hence, when stating any differences in temporal development these are based on statistical differences with p-values lower than 0.05. Generally, the variability of the data is quite high (indicated by 95 C.L.) rendering very few regression relationships as statistically different from zero. These few cases are marked by full regression lines in the figures and if it is of added value they will be commented on individually in the results section below.

3. RESULTS

3.1 Google Scholar

The search results from Google Scholar show the number of hits is by the 10's of thousands for all three live feed items. They are represented by "about" 42,200 for *Artemia*, 23,800 for rotifer and 33,500 for copepod.

3.2 Web of Science (WoS) and Aquatic Sciences and Fisheries Abstracts (ASFA)

The total numbers for each search string (both WoS and ASFA) are listed in Table 1. The number of hits in ASFA is approximately five to seven point five times higher than in WoS. It is also notable that the number of hits in WoS is much lower than for the GoS search. The hit numbers were by the hundreds to a bit more than a thousand and the rank between live feed items for the WoS search showed copepods as the lowest with rotifers coming in as second and finally *Artemia* with the highest ranking with approximately the same number of hits as the other two combined. Concerning the ASFA search, the same rank order as WoS was observed, but with hits in the thousands.

The results from the temporal WoS searches are shown in Fig. 1. For each year, the number of items resulting from each of the three search strings is shown. Total hits for 'aquaculture' was ~28,521 during 1977 – 2019, both years included. Regression models were applied to discuss trends found. An interesting observation to note is that the percentage of any given live feed key word vs. 'aquaculture' mentioned suggest that there was an increase in the total awareness of the three live feed organisms through the first half of the 1990's where the data points together reached roughly 10% and >20% in the year 1997. Thereafter, a stable declining trend happened, reaching just ≤5% during the past five years. Hence, only one out of 20 aquaculture articles mentions live feed since 2013.

In total, all three live feed items has increased exponentially in numerical awareness since the mid-1970 until present day with declining exponents following the live feed historical ontogeny with a historical successive introduction of the traditional food items and finally copepod. During the past 20 years, the annual number of articles involving live feeds range from 22-80, 14-40 and 6-53 for *Artemia*, rotifer and copepod, respectively. Moreover, it is obvious that over time *Artemia* (40-60%) and rotifer (70-20%) show a declining development whereas copepod is increasing from 10 to 20% relatively in percentage of total live feed articles since 1999 (Fig. 1). Hence, an ongoing deviation in awareness among peer-reviewed publications on the different live feed items are taking place where copepod have reached approximately one fifth of the total live feed articles the past 5 years.

3.3 World of Aquaculture Society (WAS), European Aquaculture Society (EAS) and International fish & shellfish larviculture symposia (LARVI) conferences

Concerning the following conference contributions farmed shrimps of the family Penaeidae fed with one or more of the three live feed organisms accounted for just 0.9 to 16.6% of the abstracts among the three conferences when using the search terms *penae artemia*, *penae rotifer*, and *penae copepod* . This indicate that the bulk part of the abstracts are dealing with live feed to fish larvae. We follow the historical ontogeny of when *Artemia*, rotifers and copepods were introduced as live feed organisms in larviculture. We depict three sets of sub figures for each live feed item for each of the conferences, where the first subfigure is the number of abstracts wherein a given live feed item is mentioned, the second is percentage of live feed abstracts wherein a given live feed item is mentioned, and the third is percentage of all aquaculture abstracts present at the conference wherein a given live feed is mentioned.

We reported information from 31,310 abstracts from different WAS conferences held by the various chapters over approximately the past 20 years (Fig. 2). Generally, the numerical trend lines are not different from zero indicating a quite stagnated development in the number of live feed abstracts over time with mean numerical values fluctuating around 50 for *Artemia* and rotifer and 20-30 for copepod. Likewise, the abstracts featuring live feeds mentioned *Artemia* 80% of the time whereas rotifers and copepods were mentioned 50-60% and ~20% and both not increasing with time. However, the percentages of all aquaculture abstracts at the conferences mentioning live feed declined significantly from 10 to 3% for *Artemia*, 4 to <2% for rotifers and significantly from 2 to 1% for copepods over time (Fig. 2). We also analyzed Aquaculture America and Asia-Pacific Aquaculture chapters separately with the assumption that the majority of the abstracts in each of the chapters reflected participants and studies from these specific regions. No change in patterns compared to all WAS conference abstracts were however detected (data not shown).

EAS over the past decade contribute with 4833 abstracts over a limited period; hence, the trends of data are less robust as for the other conferences (Fig. 3). Similar to what was observed with WAS, the numerical developments in abstracts each conference are stagnated and fluctuates around 50 and 25 for *Artemia* and rotifer but only from zero to 20 for copepods. For the abstracts mentioning live feed a mixed picture presents itself. *Artemia* showed a declining trend from 95% to <80% whereas rotifer fluctuates around 50% and copepod increased from <20 to 40%. The percentage of all aquaculture abstracts mentioning the live feed organisms were 6-8% for *Artemia*, ~4% for rotifer and just 1-4% for copepod, all with regression slopes not significantly different from zero.

For the more focused, but smaller in number of participants, conference series LARVI provides just 750 abstracts in total (Fig. 3). The mutual representation of the three live feed items follows the same numerical ranking as for the WAS and EAS conferences. Numerically, *Artemia* was the most prevalent with 70-80 abstracts out of all the LARVI contributions every year from 1991-2017. In the live feed abstracts, almost 100% were mentioning *Artemia* and of all conference abstract 50-70% mentioned *Artemia*. Rotifer was present with roughly 50 abstracts and 70-50% of all the live feed contributions mentioning rotifer every year from 1991-2017 whereas ~40% of all aquaculture abstracts mention rotifer. Mention of rotifers showed a declining trend over time, although it was not statistically significant. As the least mentioned live feed organism, copepod represented approximately 10 to almost 20 abstracts reflecting just 15-20% of all the live feed contributions every year from 1991-2017. However, copepods, as opposed to the low awareness in the other two conference series, they were mentioned in 10 to almost 20% of all LARVI aquaculture abstracts.

4. DISCUSSION

4.1 Major bibliometric and text mining discoveries

We have for the first time attempted to quantify the relative scientific awareness among the most important live feed for marine finfish and shrimp production by frequency of the presence of selected live feed key words in various scientific media. Our tools processed quite big amounts of data (often thousands of hits) by a bibliometric and text mining approach by searching in several media outlets with the key words *Artemia*, rotifer, copepod present in articles or conference abstracts. The numerical and/or percentage presence is used as a simple index for awareness. GoS is a platform where just about all kinds of documents are included, with no chance of quality control, which is considered needed for its use as a true bibliometric tool (*sensu* Aguillo, 2012). Hence, these limitations exclude the media for serious bibliometric analysis. Moreover, we wonder if WoS effectively catch all articles with an applied focus and suspect it to be slightly inefficient in the past, but can do a comprehensive job today. This impression is based on the fact that WoS lacks relevant rotifer articles from the 1950's to 1970's and a few aquaculture related copepod articles from the mid-1980s that we know of (e.g. Støttrup et al., 1986). The latter article has manually been included in the present analysis, but otherwise has the WoS data not been substantiated and corrected by a thorough analysis or literature information.

It is obvious that there is a timeline in which live feed organisms are used in marine fish and shrimp hatcheries. Firstly, *Artemia* was introduced in the 1930s followed by rotifers in the 1950's but first emerge in the literature databases included here in 1970's, and copepods is the latest live feed organism entering the scene in the mid-1980's (see Dhont et al., 2013). Despite its limitations, in GoS, we ran a search as an initial action to get a feeling for expected volume of our search words in the present project. Tens of thousands hits emerged for each of the three live feed organisms. The numerical chronology showed *Artemia* most numerous, interestingly followed by copepods being mentioned far more (25%) than rotifers. This is, however, in contrast to the consequent numerical chronology (with our key words *Artemia*, rotifer and copepod) presented in the following, and more transparent, databases with facilities for further analysis.

The number of reported contributions and citations in most scientific disciplines has developed exponentially, e.g. Alvarado (2016), over many years (Bornmann and Daniel, 2006), and aquaculture contributions are no different. In order to consider the overall exponential trend, we have used an anchor point/qualifier in our search and compared hits obtained by our live feed key words with an overall broader scientific frame 'aquaculture'. WoS showed a stable declining trend in mentioning one or more live feed key words vs. 'aquaculture' in WoS articles, reaching $\leq$5% in the past five years. Moreover, WAS and

EAS showed a similar or even lower fraction of abstracts mentioning live feed organisms vs. all abstracts contained in their conference proceedings. Five percent or lower of the wealth of aquaculture contributions mentioning live feed is by us considered low (Fig. 2 and 3). It is a fact that, no matter the source analyzed, *Artemia* is by far the most numerously mentioned live feed organism, followed by rotifer. This is most likely due to that they have been used for decades and is still the preferred feed items in marine hatcheries. Copepods are relatively unknown or at best new to hatcheries and therefore less used, causing less awareness. It is noteworthy that copepods, one of the by numerous researchers most promising alternative live feed for future successful marine fish larval rearing, is referred to with a relatively low frequency as it is both at WoS and at the largest comprehensive aquaculture conferences. Diversification needs new live feed protocols or else the industry most likely is destined to produce the very few marine fish species in culture today; only approximately 25 marine fish species are cultured in significant volumes according to a recent review by Nielsen et al. (2017). However, copepods seem to follow an increasing trend in EAS awareness as opposed to the traditional live feeds. Is that due to fundamental discoveries in aquaculture relevant to copepod physiology and biology contribute to being more frequently reported these years? This could be due to larger European national and EU funded research initiatives on copepods in aquaculture? We believe so and are optimistic when it comes to the increasing effect of future scientific copepod results and hope for a follow up by more intense dissemination at the mentioned comprehensive aquaculture conferences and fairs and elsewhere providing an increasing awareness (see later in 4.2).

In contrast to WAS and EAS, LARVI reveal that *Artemia* is mentioned in >50% of all the aquaculture abstracts over >25 years. As it is the most prevalent live feed used for marine fish and shrimp larvae, it is of no surprise it was highly mentioned (almost in 100% of the abstracts mentioning live feed *per se*) at this targeted conference series. Rotifer, often used as first feed in hatcheries counts 40-23% and is declining whereas copepod 10->20% and with an although not significant increasing trend of all the LARVI aquaculture contributions. Hence, copepod is still mentioned far less frequently than the others. However, this generally does not reflect the non-statistical increasing trend in copepod fraction of awareness in the WoS articles. The explanation might be that the copepod discipline is in more of a development phase and has not yet fully reached the level of practical use in the hatcheries (e.g. Nielsen et al., 2017). However, copepods in semi-extensive ponds are in fact implemented several places in Asia e.g. Vietnam (Grønning et al., 2019), and have for decades been the prime feed items in Taiwanese marine larviculture (Su et al., 2005; Blanda et al., 2015; Blanda et al., 2017) and anecdotal information from Japan and China reveal also use of copepods. In the western world we know of decade's long large scale outdoor copepod production systems in Norway (e.g. van der Meeren et al., 2014) and Denmark (Engel-Sørensen et al., 2004; Blanda et al., 2016; Hansen et al., 2016; Jepsen et al., 2017). Intensive indoor copepod rearing systems are implemented in e.g. USA (Sarkisian et al., 2019), and most likely both extensive and intensive copepod production systems exists several other places we do not know about. However, lack of a true widespread high volume use of copepods compared to the traditional live feed organisms in the industry hitherto would most likely cause less awareness at conferences and fairs and *vice versa*.

4.2 Knowledge transfer among scientists and practitioners

Our position is that far from all scientific aspects and practical shortcomings of live feed are solved at present. We would argue 'on the contrary' (see Drillet et al., 2011 and Nielsen et al., 2017). We would also like to question if sufficient knowledge about recent scientific discoveries about live feed items is available and disseminated to all the end-users. However, we must admit we have not conducted any inventory among practitioners in marine finfish hatcheries, which could have been helpful here. Hence, we must rely on our interpretation of the patterns revealed by our bibliometric analysis. According to our analysis, there is a profound difference in temporal live feed awareness between peer reviewed and large comprehensive conference sources. The dilemma is that the number of live feed reports in peer-reviewed sources are increasing exponentially with time whereas it is relatively stagnant or even declining at comprehensive conference contributions. If one accepts our premise that awareness can be monitored by our simple analysis in a (large) fraction of scientific aquaculture media, we allow ourselves to draw some conclusions. We speculate that the aquaculture industry and practitioners from e.g. hatcheries presumably, to a larger degree, attain conferences and fairs and less often study scientific book and journal articles. If this is true there is a serious risk that exposure to new research results about live feed will face a certain time-lag or even not reach these stakeholders. It is fundamental for a growing industry to get the newest results as fast as possible when released. If not, implementation of the new discoveries will not happen properly. We imagine in the worst case this problem could lead to less innovation and diversification in marine finfish production. Moreover, if we anticipate certain reluctance in the hatcheries to try something new in contrast to the usual feeding protocols, besides the newest information is not getting through, it can have drastic consequences. This reluctance can be due to lack of trustworthy proofs of concept conducted by researchers in close collaboration with the hatcheries, certain conservatism in the industry reflected in 'you know what you have and if it works to a certain degree, why change strategy?', ignorance about new discoveries or numerous other reasons related to miss targeted dissemination, of which not all is covered by the present contribution. However, we cannot exclude that it simply is due to limited or even lack of knowledge of the scientifically documented benefits e.g. copepods can bring to larval hatcheries. Moreover, it is a common perception that applied science and practitioners primarily get their knowledge from fundamental research results although with a substantial time-lag. However, recently Hansen et al. (2017) argued for that copepod physiological data obtained in applied aquaculture science activities, in fact, often enrich fundamental science with high quality data reported in journal literature. Knowledge transfer is by Hansen et al. argued to go both ways. Hence, as Louis Pasteur said "There are no such things as applied sciences, only applications of science". Therefore, it is indeed important to constantly promote multidirectional knowledge flow as recently formulated by the Editor-in-Chief for the magazine of the World Aquaculture Society: "a multi-level, multi-dimensional and multi-stakeholder collaborative approach is the best way to accelerate innovation in aquaculture going forward" (Hargreaves, 2020).

4.3 Future directions

It is a fact that the scientific community has reported many well documented alternative live feed strategies in WoS articles the past thirty years and these are ready to be tested and implemented in the marine finfish and shrimp hatchery industry. However, we suspect that practitioners only have limited knowledge regarding this. Therefore, to optimize the disseminated knowledge about live feed research results to all end users, we recommend intensified communication and meeting points established by several channels.

We envision this by 1) focusing even more on live feed at the comprehensive aquaculture conferences and fairs. This can be realized by inviting contributions for designated daylong sessions at the annual multidisciplinary arrangements or even organize thematic live feed conferences. This is relevant since a lot of effort is put into these conferences where fairs are integrated and these are attained by a broad spectrum of stakeholders. Here, LARVI serves a very important mission by inviting for the live feed discussion among scientists and potentially participants from other sectors every four years. From the present analysis, it is obvious that live feed is represented by a serious fraction of contributions at LARVI where modern concepts, like copepod applications, seems to follow a non-statistical positive trend in awareness. However, LARVI is a relatively small forum compared to WAS and EAS. LARVI could further improve participation and interaction with practitioners by e.g. inviting hatchery personal to special live feed sessions eventually by video link. This cross-sectorial invitation strategy might even inspire larger conferences e.g. WAS and EAS for an increased effort. This intensified effort of course relies on incoming suggestions for contributions by the conference attendees. 2) We are personally not systematically aware of the dissemination effort of live feed information in all the many aquaculture magazines and newspaper sources that are more available for hatchery personnel than e.g. WoS articles. Nevertheless, by systematically reading and publishing in magazines like 'World of Aquaculture', 'Aquaculture Europe', 'Hatchery Feed', 'Eurofish' and Hakai Magazine (e.g. Hansen et al., 2013; Hansen and Jepsen, 2016; Jepsen et al., 2018; Cirino, 2019) the past decade leaves the impression that in fact they do invite and bring articles about live feed. However, so far it is a minor fraction (a few percent) of the total volume of each issue that is allocated to the topic. Maybe they not receive proper input volume on the topic. Live feed scientists should intensify their contributions reporting latest results to these practitioner available media. 3) Some years ago, a group of European aquaculture scientist met at the LARVI 2013 and initiated discussions and collaboration on live feed. In 2016, a formalized network in a Thematic Group COPEAT under EAS became established. It serves the purpose as an annual meeting point at the yearly EAS conferences. At the meetings, new ideas are discussed among general live feed as well as microalgae researchers, consultants and commercial producers. The network includes at present approximately 60 European participants representing these sectors. COPEAT regularly releases a newsletter with short, focused articles about live feed innovations and reports from various aquaculture conferences and workshops by participants in the network. It would be relevant if more practitioners were invited into the network, as they can formulate their needs to the researchers as well as catalyze and intensify the dialog between the sectors. 4) Practical collaboration between governmental/university researchers and hatcheries is a proven way to generate larger scale demonstrations and show-cases of new improved live feed protocols as nicely demonstrated for *Artemia* by the Laboratory of Aquaculture & Artemia Reference Center (ARC) hosted at Ghent University in Belgium (https://www.ugent.be/bw/asae/en/research/aquaculture). This long-time exemplary initiative has led to widespread bilateral knowledge transfer to/from researchers to practitioners via e.g. a commercial company INVE. The organization structure and sector integration could benefit the future implementation of other live feeds e.g. copepods in hatcheries as well. This latter has, however, to a certain extent, taken place during interaction of copepod researchers, the present users and the few large scale producers of calanoid copepods, leading to the copepod producing companies CFEED delivering copepod eggs (https://www.cfeed.no) and Planktonic AS delivering cryopreserved copepods and cirriped nauplii (https://www.planktonic.no) in Norway and Fry Marine in Holland delivering copepod eggs (https://www.frymarine.nl). Such collaboration generates knowledge transfer effectively and promotes new thoughts spreading among the hatcheries with feedback to the producers. Scientists, practitioners and funding bodies should generally collaborate more intensely and generate targeted live feed initiatives of relevance for the future. 5) Designated hands-on live feed courses with focus on the newest knowledge that could be offered more to hatchery personnel by university researchers. There certainly exists such days to week-long intensive hands-on courses held in e.g. Africa (Aquaculture Innovations, https://www.Aquaafrica.co.za) and Asia (Aquaculture Asia, https://www.aquaculture.asia/pages/36.httml; Agriinnovate India, https://www.agriinnovateindia.co.in; and ICAR-Central Institute of Brackish water Aquaculture, Chennai, India, https://www.ciba.res.in). However, after searching thoroughly, we have not found any courses on modern live feed technologies offered in Europe, Australia or the Americas. The advertised courses we found there all deal with the traditional zooplankton feed items rotifers and, in particular, *Artemia* with an emphasis on cultivation and enrichment issues. To the best of our knowledge, no one has yet taken up the task offering rearing courses on alternative zooplankton live feed. Here use of open educational resources (OER) initiatives associated with higher education institutions potentially can support the enhancement of a skilled workforce in aquaculture (*sensu* Pounds and Bostock, 2019). Also e-learning tools are a powerful media to reach stakeholders in the public domain (e.g. Sexias et al., 2014). Moreover, when live feed contributions of relevance for end-users are released in scientific journals, the authors should strive towards open access. That exposes the material for free to the public. 6) More than a decade ago (2008), a homepage about copepod cultures around the World was established and hosted at our home University, Roskilde University, Denmark. It was managed by Dr. Gael Dur (at that time PhD student Université Lille, France) and Dr. Guillaume Drillet (at that time PhD student at our university and recently president of WAS Asian-Pacific chapter) (Drillet and Dur, 2008; 2009). The homepage included information on copepod species, strain number, cultivation protocols and other important information that could benefit newcomers to copepod rearing and in dialog with experienced copepodologists. However, due to leaving their host institutions for career development and a lack of resources and proper attention from Roskilde University's side, it was principally given up in 2012. Such a platform could relatively easy be revitalized and maintained and act as yet another meeting point for researchers and practitioners. The same idea was fortunately taken up resulting in a complete list of aquaculture relevant copepod species in culture published in a 266 page long open access scientific book "Dedicated to the coastal fisher-folks and fish farmers" by Perumal et al. (2015). In that book, the authors summarize all the benefits copepods could bring into marine finfish production. In conclusion, here we propose several pathways and initiatives to disseminate the newest live feed knowledge on not only copepods but principally on all zooplankton live feed organisms obtained by researchers to everyday use in marine hatcheries increasing their awareness for alternatives to the traditional live feed organisms. There are most likely more initiatives that would benefit that mission; let's start the process together.

5. CONCLUSIONS

We have based on a bibliometric analysis revealed a decreasing awareness in written and oral reports on live feed issues in conference proceedings over the past decades. If there is a desire from consumers and the aquaculture industry to optimize existing marine fish and shrimp hatchery productivity and diversify marine fish larvae cultivation practices, then providing high quality live feed products should be taken more seriously. This is an important contributor in solving one of marine finfish production bottlenecks. Despite a willingness to embrace innovation in the aquaculture sector we do not experience much implementation of alternative live feed items in marine finfish and shrimp hatcheries. Increasing the mutual awareness in relevant fora on the constant flow of new results from live feed research can be achieved simply by intensifying the oral and written dialog in relevant settings between scientists and practitioners. We believe it is a matter of effective dissemination of which we have given some suggestions ultimately leading towards easier access to a suite of high quality live feed products tailored to every existing and future species of marine fish larvae in culture.

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Conflict of interest

Researchers from the Laboratory of Aquaculture & Artemia Reference Center (ARC), Ghent University, and from the company INVE aquaculture, Belgium.

Author contribution

BWH formulated the idea, contacted the data managers of the scientific societies, discussed data treatment and interpretation, wrote the bulk part of the article, and communicated with the journal.

SM wrote the script code, processed all data, conducted all statistics, generated all graphics, and commented on drafts.

REFERENCES

Abate, T. G., Nielsen, R., Nielsen, M., Drillet, G., Jepsen, P. M., & Hansen, B. W. (2015). Economic feasibility of copepod production for commercial use: Result from a prototype production facility. Aquaculture, 436, 72-79.

Aguillo, I. F. (2012). Is Google Scholar useful for bibliometrics? A webometric analysis. Scientometrics, 91, 343-541.

Alvarado, R. U. (2016). Growth of Literature on Bradford's Law. Investigación Bibliotecológica: Archivonomía, Bibliotecología e Información, 30, 51-72.

Aquatic Sciences and Fisheries Abstracts (ASFA). https://search.proquest.com /asfa/productfulldescdetail

Basford, A. J., Mos, B., Mishina, T., & Dworjanyn, S. A. (2019). Oyster larvae as a potential first feed for small-mouthed ornamental larval fish. Aquaculture Environment Interactions, 11, 657–669.

Blanda, E., Drillet, G., Huang, C. C., Hwang, J.-S., Jakobsen, H. H., Rayner, T. A., Su, H. M., Wu, C. H., & Hansen, B. W. (2015). Trophic interactions and productivity of copepods as live feed from tropical Taiwanese outdoor aquaculture ponds. Aquaculture, 445, 11-21.

Blanda, E., Hansen, B. W., Højgaard, J. K., Jepsen, P. M., Pedersen, M. F., Rayner, T. A., Thoisen, C. V., & Jakobsen, H. H. (2016). Inorganic nitrogen addition in a semi-intensive turbot larval aquaculture system: effects on phytoplankton and zooplankton composition. Aquaculture Research, 47, 3913-3933.

Blanda, E., Drillet, G., Huang, C. C., Hwang, J.-S., Højgaard, J. K., Jakobsen, H. H., Rayner, T. A., Su, H. M., & Hansen, B. W. (2017). An analysis of how to improve production of copepods as live feed from tropical Taiwanese outdoor aquaculture ponds. Aquaculture, 497, 432-441.

Borja, A., Andersen, J. H., Arvanitidis, C. D., Basset, A., Buhl-Mortensen, L., Carvalho, S., Dafforn, K. A., Devlin, M. J., Escobar-Briones, E. G., Grenz, C., Harder, T., Katsanevakis, S., Liu, D., Metaxas, A., Morán, X., A. G., Newton, A., Piroddi, C., Pochon, X., Queirós, A. M., Snelgrove, P. V. R., Solidoro, C., St. John, M. A., & Teixeira, H. (2020). Past and Future Grand Challenges in Marine Ecosystem Ecology. Frontiers of Marine Science, 7, 362. doi: 10.3389/fmars.2020.00362

Bornmann, L., & Daniel, H.-D. (2006). What do citation counts measure? A review of studies on citing behavior. Journal of Documentation, 64, 45-80.

Cirino, E. (2019). Is this tiny copepod the key to sustainable producing omega 3s? Hakai Magazine – Coastal science and societies, January 24th 2019.

Conceição, L. E. C., Yúfera, M., Matridis, P., Morais, S., & Dinis, M. T. (2010). Live feeds for early Stages of fish rearing. Aquaculture Research, 41, 613-640.

Das, P., Mandal, S. C., Bhagabati, S. K., Akhtar, M. S., & Singh, S. K. (2012). Important live food Organisms and their role in aquaculture. P. 69-86 In: Frontiers in Aquaculture Ed. Sukham, M. 1. Edition. Narendra Publishing House, New Delhi, India.

Dhert, P., Rombaut, G., Suantika, G., & Sorgeloos, P. (2001). Advancement of rotifer culture and manipulation techniques in Europe. Aquaculture, 200, 129-146.

Dhont, J., Dierckens, K., Støttrup, J., Van Stappen, G., Wille, M., & Sorgeloos, P. (2013). Rotifers, *Artemia* and copepods as live feeds for fish larvae in aquaculture. In: Advances in Aquaculture Hatchery Technology. Eds. Allan, G,& Burnell, G., vol. 242, Woodhead, 2013, pp. 157–202. Woodhead Publishing, Cambridge, ISBN (Print) 978 0 85709 119 2

Do, Y., & Skłodowski, J. (2014). Research topics and trends over the past decade (2001-2013) of Baltic Coleopterology using text mining methods. Baltic Journal of Coleopterology, 14, 1-6.

Do, Y., Ko, E. J., Kim, Y.-M., Kim, H.-G., Joo, G.-J., Kim, J. Y., & Kim, H.W. (2015). Using Text-Mining Method to Identify Research Trends of Freshwater Exotic Species in Korea. KJEE, 48(3): 195-202. [in Korean with abstract, figures and associated texts and list of references in English].

Drillet, G., & Dur, G. (2008). Providing new tools for scientist: the world copepod culture database Roskilde University. Poster session presented at the 10th International conference on Copepoda, 10-15 July Pattaya, Thailand.

Drillet, G., & Dur, G. (2009). Progress on the Copepod Culture Database. MONOCULUS Copepod Newsletter 57, World Association of Copepodologists, 17, 3.

Drillet, G., Frouël, S., Sichlau, M. H., Jepsen, P. M., Højgaard, J. K., Joarder, A. K., & Hansen, B. W. (2011). Status and opinion of marine copepods for use as live feed. Aquaculture, 315, 155-166.

Engell-Sørensen, K., Støttrup, J. G., & Holmstrup, M. (2004). Rearing of flounder (*Platichthys flesus*) juveniles in semiextensive systems. Aquaculture, 230, 475-491.

FAO (2018). The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome. 227 pp. Licence: CC BY-NC-SA 3.0 IGO. ISBN 978-92-5-130562-1 Google Scholar (GoS). https://scholar.google.com

Grønning, J., Doan, N. X., Dinh, N. T., Dinh, K. V., & Nielsen, T. G. (2019). Ecology of *Pseudodiaptomus Annandalei* in tropical aquaculture ponds with emphasis on the limitation of production. Journal of Plankton Research, 41, 741-758.

Hansen, B. W., Drillet, G., Jepsen, P. M., & Rayner, T. A. (2013). Copepods natures choice. Hatchery Feed, 1, 9-12.

Hansen, B. W., & Jepsen, P.M. (2016). Copepods, a promising live feed for farmed fish and shrimp larvae. Eurofish Magazine, 6, 15-16.

Hansen, B. W., Blanda, E., Drillet, G., Højgaard, J. K., Mahjoup, M. S., & Rayner, T. A. (2016). Outdoor rearing facilities of free spawning calanoid copepods for turbot larva can host a bank of resting eggs in the sediment. Aquaculture International, 24, 949-964.

Hansen, B. W., Jepsen, P. M., & Drillet, G. (2017). Applied and fundamental plankton research would benefit from more joint efforts: examples from *Acartia tonsa*. Journal of Plankton Research, HORIZONS contribution, 39, 975-983.

Hargreaves, J. A. (2020). A Snapshot of Current Aquaculture Innovation. World Aquaculture. The magazine of the World Aquaculture Society, 51(3), 3.

Howell, B. R. (1971). Rearing the larvae of the lemon sole, *Microstomus kitt*, Walbaum, on cultured foods. ICES Journal of Marine Science, 35, 1–6.

Izquierdo, M., & Koven, W, (2011), Lipids. In G.J. Holt (Ed.) Larval Fish Nutrition (pp. 47-82) John Wiley & Sons, Inc. ISBN 978-0-8138-1792-7

Jepsen, P. M., Jakobsen, H. H., Rayner, T. A., Blanda, E., Novac, A., Engell-Sørensen, K., & Hansen, B. W. (2017). A production season of turbot larvae *Scophthalmus maximus* (Linnaeus, 1758) reared on copepods in a Danish semi-intensive outdoor system. Aquaculture Research, 48, 4958-4974.

Jepsen, P. M., Nielsen, B. L. H., Greve, H. v. S., & Hansen, B. W. (2018). Copepods as live feed, what is all the fuss about? Hatchery Feed, 6(4),14-16.

Kostoff, R. N., Toothman, D. R., Eberhartc, H. J., & Humenik, J. A. (2001). Text mining using database tomography and bibliometrics: A review. Technological Forecasting & Social Change, 68, 223–253.

Lubzens, E., Tandler, A., & Minkoff, G. (1989). Rotifers as food in aquaculture. Hydrobiologia, 186/187, 387-400.

Lund, I., Steenfeldt, S. J., Banta, G. T., & Hansen, B. W. (2008). The influence of dietary concentrations of arachidonic acid and eicosapentanoic acid at various stages of larval ontogeny on eye migration, pigmentation and prostaglandin content of common sole larvae (*Solea solea* L.). Aquaculture, 276, 143-153.

Mahjoub, M. S., Schmoker, C., & Drillet, G. (2013). Live feeds in larval fish rearing: production, use, and the future. P. 41-71. In: Larval Fish Aquaculture. Ed. Qin, J.G. Nova Science Publishers, Inc. OUI. ISBN: 978-1-62417-899-3.

Nielsen, R., Nielsen, M., Abate, T. G., Hansen, B. W., Jepsen, P. M., Nielsen, S. L., Støttrup, J., & Buchmann, K. (2017). The importance of live-feed traps - farming marine fish species. Aquaculture Research, 48, 2623-2641.

Perumal, S., Ananth, S., Nandakumar, R., Jayalakshmi, T., Kaviyarasan, M. & Pachiappan, P. (2015). Intensive Indoor and Outdoor Pilot-Scale Culture of Marine Copepods. In: Advances in Marine and Brackish water Aquaculture. Ed. Perumal, S., Thirunavukkarasu, A. R., & Pachiappan, P. pp. 33-42. Springer India. ISBN 978-81-322-2270-5 (print). ISBN 978-81-322-2271-2 (eBook).

Pounds, A., & Bostock, J. (2019). Open educational resources (OER) in higher education courses in aquaculture and fisheries: opportunities, barriers, and future perspectives. Aquaculture International, 27, 695-710.

Randazzo, B., Rolla, L., Ofelio, C., Planas, M., Gioacchini, G., Vargas, A., Giorgini, E., & Olivotto, I. (2018). The influence of diet on the early development of two seahorse species (*H. guttulatus* and *H. reidi*): Traditional and innovative approaches. Aquaculture, 490, 75-90.

Rasdi, N., & Qin, J. G. (2014). Improvement of copepod nutritional quality as live food for aquaculture: a review. Aquaculture Research, 47, 1-20.

Rayner, T. A., Hwang, J.-S., & Hansen, B. W. (2017). Minimizing the use of fish oil enrichment in live feed by use of a self-enhancing calanoid copepod *Pseudodiaptomus annandelei*. Journal of Plankton Research, 39, 1004-1011.

Sarkisian, B. L., Lemus, J. T., Apeitos, A., Blaylock, R. B., & Saillant, E. A. (2019). An intensive, large-scale batch culture system to produce the calanoid copepod, *Acartia tonsa*. Aquaculture, 501, 772-778.

Sexias, S., Dove, C., Ueberschar, B., & Bostock, J. (2014). Evaluation on the use of e-learning tool to support teaching and learning in aquaculture and aquatic resource management education. Aquaculture International, 23, 825-842.

Shields, R. J., Bell, J. G., Luizi, F. S., Gara, B., Bromage, N. R., & Sargent, J. R. (1999). Natural Copepods are superior to enriched Artemia nauplii as feed for halibut larvae (*Hippoglossus hippoglossus*) in terms of survival, pigmentation and retinal morphology: relation to dietary essential fatty acids. Journal of Nutrition, 129, 1186-1194.

Smith, H., & Basurtu, X. (2019). Defining Small-Scale Fisheries and Examining the Role of Science In Shaping Perceptions of Who and What Counts. Frontiers of Marine Science, 07 May 2019 | https://doi.org/10.3389/fmars.2019.00236.

Støttrup, J. G., Richardson, K., Kierkegaard, E., & Pihl, N. J. (1986). The cultivation of *Acartia tonsa* Dana for use as a live food source for marine fish larvae. Aquaculture, 52, 87-96.

Støttrup, J. G., & McEvoy, L. A. (eds.) (2003) Live Feeds in Marine Aquaculture. 318 pp. Wiley, Blackwell Science Ltd. ISBN:9780632054954.

Su, H. M., Cheng, S. H., Chen, T. I., & Su, M. S. (2005). Culture of Copepods and Applications to Marine Finfish Larval Rearing in Taiwan. In: Copepods in Aquaculture (eds. Lee C-S, P., O'Bryen P. J., & Marcus, N. H.), pp 183-194. Oxford, UK: Black Publishing Ltd.

Van der Meeren, T., Karlson, Ø., Liebig, P. E., & Mangor-Jensen, A. (2014). Copepod production in a saltwater pond system: A reliable method for achievement of natural prey in start-feeding of marine fish larvae. Aquaculture Engineering, 62, 17-27.

Web of Science (WoS). https://webofknowledge.com

Wilcox, J. A., Tracy, P. L., & Marcus, N. H. (2006). Improving live-feeds: effect of a mixed diet of Copepod nauplii (*Acartia tonsa*) and rotifers on the survival and growth of first-feeding larvae of the southern flounder, *Paralichtys lethosigma*. Journal of the World Aquaculture Society, 37, 113-120.

Øie, G., Reitan, K. I., Evjemo, J. O., Støttrup, J., & Olsen, Y. (2011). Live feeds. In Holt. G. J. (Ed.), Larval Fish Nutrition (pp. 307-334). John Wiley & Sons, Inc. ISBN 978-0-8138-1792-7.

Figures

FIGURE 1 Web of Science (WoS) search results in articles for each of the three search strings mentioned in Table 2. Temporal development of articles from 1977 to 2019 about live feed organisms, *Artemia*, rotifer and copepod divided into three categories: number of abstracts mentioning a particular live feed organism [Y = exp(aX+b) where a = year, X = exponent and b = intercept)], percentage of all live feed abstract mentioning a given live feed organism, and percentage of all aquaculture abstracts mentioning a given live feed organism (modelled by linear regression). Full regression line indicate that the slope is statistically different ($p < 0.05$) from zero whereas a broken regression line indicates no significant difference.

FIGURE 2 Temporal development of WAS conference abstracts from 1996 to 2017 about live feed organisms, *Artemia*, rotifer, and copepod divided into three categories: number of abstracts mentioning a particular live feed organism, percentage of all live feed abstract mentioning a given live feed organism, and percentage of all aquaculture abstracts mentioning a given live feed organism (modelled by linear regression). Full regression line indicate that the slope is statistically different ($p < 0.05$) from zero whereas a broken regression line indicates no significant difference.

FIGURE 3 Temporal development of EAS conference abstracts from 2001 to 2017 (blue symbols and lines) and LARVI conference abstracts from 1991 to 2017 (red symbols and lines) about live feed organisms, *Artemia*, rotifer, and copepod divided into three categories: number of abstracts mentioning a particular live feed organism, percentage of all live feed abstract mentioning a given live feed organism, and percentage of all aquaculture abstracts mentioning a given live feed organism (modelled by linear regression). Full regression line indicate that the slope is statistically different ($p < 0.05$) from zero whereas a broken regression line indicates no significant difference.

TABLE 1 Web of Science (WoS) search results and Aquatic Sciences and Fisheries Abstracts (ASFA) search results between 1900 and present when visited October 30, 2020.

WoS search string	**Number of hits (WoS)**	**Number of hits (ASFA)**
(aquacultu* OR "live feed*" OR "live food") AND artemia*	1126	5541
(aquacultu* OR "live feed*" OR "live food") AND rotif*	708	3949
((aquacultu* OR "live feed*" OR "live food") AND (copepod*)) NOT ("sea lice" OR "salmon louse" OR parasit*)	460	3413

TABLE 2 Regression parameters for figure 2 and 3.

Regression parameters for WAS abstract results (linear model)

	Number of abstracts				**Percentage of live feed abstracts**				**Percentage of all abstracts**			
	Intercept	Slope	R^2	P	Intercept	Slope	R^2	P	Intercept	Slope	R^2	P
Artemia	-729.1	0.392	0.008	0.689	162.2	-0.417	0.001	0.884	303.9	-0.149	0.419	0.001
Rotifera	-205.2	0.121	0.003	0.812	1007.8	-0.475	0.111	0.130	244.7	-0.120	0.679	$2.43*10^{-6}$
Copepod	-810.7	0.414	0.105	0.141	-363.6	0.196	0.024	0.495	91.8	-0.045	0.204	0.035

Regression parameters for EAS abstract results (linear model)

	Number of abstracts				**Percentage of live feed abstracts**				**Percentage of all abstracts**			
	Intercept	Slope	R^2	P	Intercept	Slope	R^2	P	Intercept	Slope	R^2	P
Artemia	1588.6	-0.769	0.014	0.782	4362.7	-2.127	0.523	0.043	400.3	-0.196	0.200	0.267
Rotifera	-315.8	0.170	0.002	0.919	-751.4	0.399	0.033	0.663	11.2	-0.004	0.0002	0.974
Copepod	-3458.4	1.726	0.300	0.160	-5932.5	2.963	0.608	0.023	-490.0	0.245	0.336	0.132

Regression parameters for LARVI abstract results (linear model)

	Number of abstracts				**Percentage of live feed abstracts**				**Percentage of all abstracts**			
	Intercept	Slope	R2	P	Intercept	Slope	R2	P	Intercept	Slope	R2	P
Artemia	-852.4	0.469	0.016	0.787	182.9	-0.043	0.020	0.758	-1245.3	0.652	0.123	0.441
Rotifera	1355.9	-0.652	0.336	0.173	1532.7	-0.736	0.331	0.177	474.3	-0.219	0.196	0.320
Copepod	-118.7	0.066	0.0418	0.660	-486.7	0.251	0.144	0.401	-410.2	0.210	0.326	0.180